STORMWATER MANAGEMENT

Emerging Planning Approaches and Control Technologies

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Preface

The intent of the manual is to keep individuals who are involved with urban drainage and stormwater management in provincial agencies, municipalities, conservation authorities and private industries informed of the most up-to-date strategies and practices for stormwater management. The practice of stormwater management has been rapidly evolving over the past decade. This manual peeks into the experience of the past and is putting together current planning approaches and management practices which are found acceptable to the various reviewing agencies. As this manual is prepared months ahead of the actual day of the training session, it is important to realize that some of the "current" practices discussed in the manual could have become out dated on the day when the training is held.

Although some practical, specific guidance have been cited, it should be stressed that there must be flexibility to account for site specific conditions. Site specific conditions/characteristics will govern over the guidance provided in the manual.

As new innovative control or preventive technologies emerge, it is encouraged that such designs be considered for approval if the designers can show that these alternate approaches can produce the desire results. There is a need for innovative designers to develop better designs and for reviewing agencies to encourage innovation by showing flexibility in applying agency criteria.

Lastly, the list of computer models discussed in the training session is, by no means, exhaustive. The list may reflect the more popularly applied models currently available. There are many other computer models which are equally practical and more are expected to be developed. Selection of models should be done with care and this can be achieved by going through a list of model selection criteria, for example, continuous or single event, evaluation of control options, water quality routing, sewer shapes, etc. Finally, the ability of the modeller to interpret correctly the results of the modelling exercise is of vital importance.

Comments and queries regarding this document may be sent to:

Ministry of Environment and Energy
Program Development Branch
Urban and Rural Programs Section
40 St. Clair Avenue West, 14th Floor
Toronto, Ontario
M4V 1M2
Attn. Jonathan P'ng

Tel. (416) 314-3912
Fax (416) 314-3918

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CHAPTER 1

URBAN STORMWATER MANAGEMENT

CHAPTER 1

1.1 INTRODUCTION

1.1.1 Training Objectives

The objectives of this Chapter are to:

- provide an overview of the impacts of urbanization on the hydrologic cycle
- describe how those alterations of the hydrologic cycle, and other consequences of urbanization, can affect the environment, and
- provide an introduction to the concept of stormwater management

1.1.2 Urban Stormwater Management

Stormwater management as an area of engineering practice is readily understood and defined. However, the term must be approached with caution since the practice of stormwater management has evolved rapidly over the last ten years, and will no doubt continue to do so for the foreseeable future. As recently as the late 1970's, stormwater management associated with urban development was generally restricted to the practice of drainage engineering. At that time, the objective of stormwater management was essentially to convey stormwater flows from a development conveniently, safely, and at low cost. Flood protection was a separate consideration, and was mostly directed at provision of hydraulic drainage structures adequate to contain and convey flood flows.

These seem like reasonable objectives in themselves, and in fact must still be respected. However, these objectives are not sufficient, since they do not eliminate secondary effects such as environmental damages caused by upstream development. To address such secondary effects, drainage engineering as a sole concern is now rare, and stormwater management in an increasingly holistic form is the rule.

Presently, stormwater management encompasses a whole array of considerations, including water quantity and quality, habitat, groundwater recharge, baseflow augmentation, and other aspects of the environment. Reconciling the needs of these environmental sensitivities while fulfilling the primary requirement for safe and effective drainage of stormwater is the challenge of stormwater management.

*... the planning and control of drainage
so as to preserve life and prevent damage during storm events,
while respecting the need to
preserve and protect environmental features
that might directly or indirectly
be affected by changes in storm flows.*

A Working Definition of Stormwater Management

1.2 THE IMPACTS OF URBANIZATION ON THE WATER RESOURCES SYSTEM

1.2.1 General

The process of urbanization affects the hydrologic cycle in a number of significant ways. These include impacts on the volume of runoff, the rate of runoff, and the water quality of runoff, etc.

Rate and Volume of Runoff in the Natural Setting

In natural or undeveloped conditions, the runoff hydrograph (runoff flow rates over time) tends to be relatively flat and small compared to what is observed after urbanization. This reflects the hydrologic processes governing infiltration losses and surface routing.

In the natural condition, there is relatively little impervious area on the watershed surface unless intact rock, clay, or water surfaces are present. Therefore in natural soils with vegetative cover substantial volumes of rainfall are lost, first to initial wetting of vegetation and ground cover, and then as a result of infiltration into the ground. In sandy areas with a high soil moisture capacity, the natural volume of runoff can be relatively low. A volumetric runoff coefficient (volume or runoff/ volume of rainfall) in the vicinity of 0.2 or 0.3 can be experienced.

Also, the natural vegetation and uneven terrain tend to hold back runoff. Small ponding areas on the uneven land surface will hold back flow, and flow paths are irregular and meandering. Also, small volumes of flow imply low depths of overland flow and hence low flow velocities overland. Taken together, these factors tend to extend the time which must elapse before flow volumes can leave the watershed.

The net result of low flow volume and a strong surface routing effect is that the undeveloped hydrograph is generally flat and low.

Rate and Volume of Runoff in the Developed Setting

Urban development inevitably changes the watershed, by paving, regrading, adding drainage facilities, and removal or alteration of vegetation. This has a strong influence on both the amount of water which infiltrates, and the rate at which water moves across the catchment.

The removal of natural vegetation and grading of the land eliminates storage associated with interception of rainfall by vegetative cover. Covering the land surface with pavement and concrete prevents infiltration, and hence, effectively eliminates substantial amounts of available soil moisture storage. These factors tend to increase the amount of runoff volume which is associated with a give rain event, compared to the natural condition. Runoff volume coefficients may be has high as 0.8 or 0.9 on an event basis after development. In extreme cases, therefore, development can raise the volume of runoff several times over what is observed naturally.

The surface routing system is also profoundly affected by development. The land surface, graded and manicured to typical urban standards, demonstrates less opportunity for ponding. As well, overland flow routes are less meandering and therefore tend to provide steeper and shorter flow routes. Velocities are therefore higher, and hydrographs tend to be peakier.

Even more extreme changes in the surface routing system are associated with the urban drainage infrastructure. Pipes and gutters or roadways tend to be more direct, steeper, and smoother pathways for water than exist in natural catchments. As well, such structures concentrate flow in defined channels which have relatively less volume than the pre-existing overland surface system. This further reduces the routing effect, compared to the natural case. Again, for a given volume of runoff, flow rates are faster.

Figure 1.1 shows the effect of urbanization on runoff hydrographs.

- imperviousness increases
- vegetative cover changes
- overland flow routes become quicker
- pipes and gutters tend to increase flows

Changes Affecting Runoff Rate and Volume

Changes in the Channel System

The other major change in the hydrologic system which is associated with urbanization is associated with the drainage network which receives flows. The natural system includes channels which arise naturally as flows cut defined drainage pathways through low points. These natural channels tend to meander, and maintain a net slope that balances the rate of flow, the channel material, and the overall land form of the area. The natural channel form generally has a narrow, meandering channel which conveys flows between events, and during small storms. Also, however, there is a larger floodway which has the capacity to convey flows during larger storm events. This floodway is an important facet of the watershed drainage system, since the floodway not only provides a major hydraulic capacity, but provides a substantial volume for flow routing and peak flow attenuation.

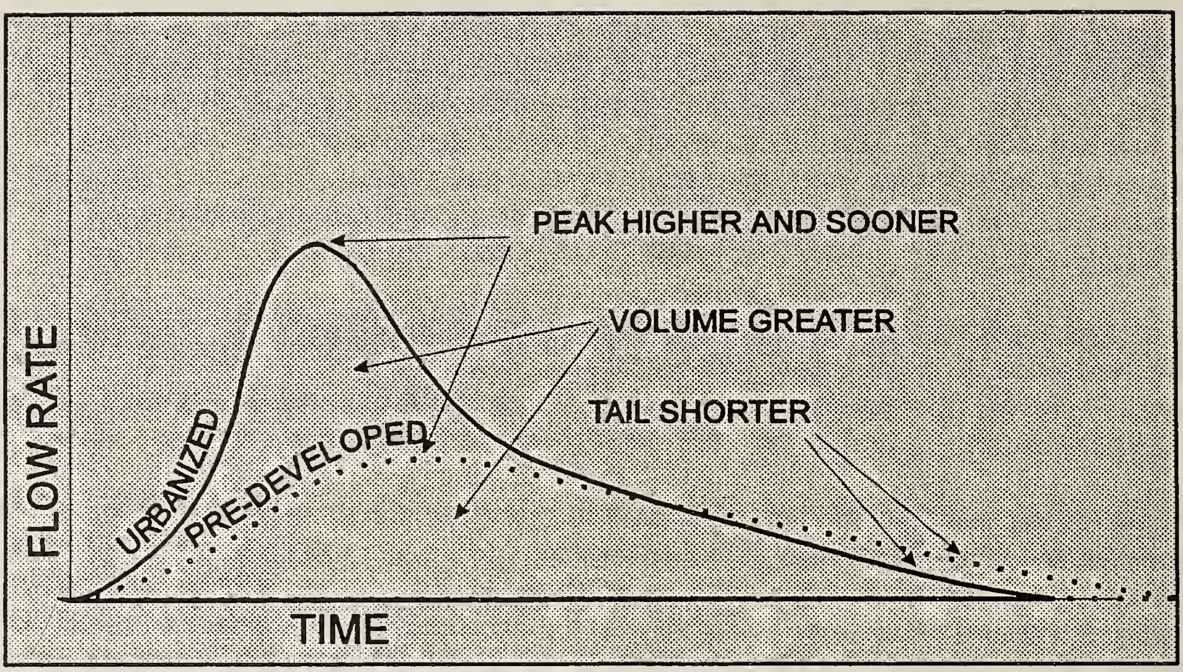

Figure 1.1: Conceptual Sketch of Changes in Hydrograph

However, historical land development practice tended to promote encroachment of the floodway by human structures or other factors. Fill along the edge of the floodway tended to progressively narrow it. Channelisation to stabilise the channel, or re-direct it to conform to street patterns or other 'desirable' conditions also had an impact. The channelised creek or river tended to be straighter and smaller in section than the natural system. As a result, the channel was steeper, smoother, and possessed of a smaller storage volume. Again, the tendency is for urbanisation to cause higher, larger flow hydrographs.

- encroachment by structures
- reduced storage due to fill or encroachment
- realignment to accommodate urban form

Typical Affects of Urbanization on Stream or River Channels

Water Quality

Water quality degradation also accompany the change to an urban environment. There is a tendency for the changes in land use to be associated with different sources of pollution. The nature of this change is associated with the existing and future land use. A shift from cattle farming to light industry, from example, is not equivalent to the shift from deciduous forest to single family residential neighbourhoods. However, there are a number of generalizations that can be made, to illustrate the nature of the problem.

- Vehicle traffic is probably one of the most significant impacts on water quality. Leaded gas, electrical components, catalytic converters, exhaust emissions, fuels and lubricants, and other factors are or have been all associated with the automobile. Snow removal operations implicitly contribute quantities of de-icing compounds, mainly salts.

- Animal populations also are affected by urbanization. Free roaming pets have been documented as substantial contributors to indicator bacteria. Shifts in bird populations have also been associated with increased indicator bacteria loads.

- Combined Sewage Overflows are a major consideration in stormwater and sanitary system servicing upgrades in many North American cities. Such overflows are not strictly a problem of stormwater management, but are commonly encountered as stormwater quality problems are solved.

- Land application of pesticides, herbicides, and fertilizers accompany the urban dwellers' attempts to improve on the appearance of lawns and gardens.

- Suspended sediment loads are affected by changes in land use. Loads may go down after urbanization, in fact, compared to what might be encountered in some agricultural operations. However, the sediments may have an associated chemical constituent load which is different from that which is encountered naturally.

- Temperature can be affected, as the shift in land cover and stream vegetation alters the balance of radiation and hence land and runoff temperature. Also, a tendency for baseflow to decrease in favour of direct runoff can have an effect on instream temperature.

In general, one might expect changes in water borne loads of heavy metals, organic compounds, indicator bacteria or pathogens, oxygen demanding substances, water temperature, dissolved oxygen, and suspended sediments among other things after urbanization. Floating materials such as styrofoam particles, oils and greases, or other debris also are a consequence of urbanization.

- indicator bacteria and pathogens may increase
- BOD increases, and DO decreases
- suspended sediments change (typically increase)
- temperature increases
- anthropogenic floatable materials increase
- organic compounds can increase
- chlorides can increase

Some Water Quality Impacts

In general, the impact of urbanization can be widespread and considerable, indirectly or directly affecting many aspects of the watershed and receiving waters as a result of the ways in which urban development affects the hydrologic cycle, and the physical components which regulate that cycle.

- increased flooding
- reduced base flow
- channel instability
- impaired water quality
- increased erosion or deposition
- lowered water table
- impaired habitat

Some General Consequences of Urbanization, Induced by Changes to the Hydrologic System

1.2.2 Flooding

The process of urban development in Ontario very often progressed upstream from a river junction or outlet which originally spawned the development of a community. This was the case, for example, along much of the Lake Ontario shoreline.

A predictable pattern was found to accompany this development. An initial development might be at the outlet of a stream. Drainage works for the initial development were sized and placed to provide flood protection. This might include drainage to the river, or lake. If channel capacity was adequate, channelization might not occur. Drainage would initially be adequate, and where is was not, would be countered with local channelization or flood protection. Flow peaks and volumes might increase, but these were handled as a part of the initial design, and were not a major problem otherwise.

Then, development would progress upstream, as the older development area expanded into adjacent lands in response to the pressure for growth. Drainage works in the new area would be again be designed to be locally adequate. However, flows from the new development would also increase compared to undeveloped conditions, as a result of the impacts on the hydrologic cycle described above.

These upstream increases might be accommodated by the downstream drainage system initially. Eventually, however, a point would be reached where the cumulative impact of upstream development increased flows to the point that drainage in the earlier development areas downstream might not be adequate. Flooding would ensue, and drainage works would be placed downstream in an effort to contain the damage. However, responding to such problems is not always simple. Structures such as houses built on or across the flood plain represent a special challenge.

- development begins at the lower end of the watershed
- natural and human factors are sensitive to flow increases
- upstream development occurs, and increases runoff upstream
- downstream developments experience increased frequency and severity of flooding

The Typical Relation Between Urban Development and Flood Potential

Eventually, it became recognized that the solution to flooding would ideally be to guide development so as to respect basic principles that mitigate the problem before it is encountered. It might, for example, be appropriate to:

- avoid changing the rates at which flows are released from a development area compared to what existed before development,

- avoid encroachment on the river floodway by structures that might compromise hydraulic conveyance, reduce storage routing, or be susceptible to damage

- encourage development practices that reduce runoff volumes to an approximation of natural conditions

- regulate development within flood plains.

These are structural and management elements of stormwater management that are focused on mitigation of flooding.

1.2.3 Impacts on Base Flow

Urbanization tends to result in more water runs off the catchment than before development. Recharge of the groundwater system is therefore reduced (infiltration is reduced). In turn, this affects the baseflow in a stream, since base flow is often largely composed of waters which exfiltrate from the groundwater storage system between events. One can view the soil system as a reservoir which fills during events, and empties into the channel between events. If this reservoir is capped, the recharge part of the water cycle is reduced. As a result, the reservoir becomes depleted, and baseflows are reduced. In general, the process of urbanization therefore tends to change streamflows from one form to another; base flows are reduced, flood events become peakier and larger, and the whole system tends to be much less damped than before development.

- imperviousness increases
- recharge is reduced
- soil moisture is depleted
- exfiltration to the river is decreased
- baseflow is reduced

and

- water quality and temperature are affected

Typical Impacts of Urbanization on Base Flow

Reductions in baseflow can affect aquatic species and their habitats, as well as recreational uses and water supply potential of lakes and rivers.

The responses of stormwater management to this phenomenon include:

- promotion of stormwater management practices that encourage infiltration and groundwater recharge.

- promotion of drainage practices that encourage buffering, retention, and slow release of stormwater flows where appropriate

1.2.4 Water Quality

As indicated above, the shift in land use has a direct consequence, in that the contaminants in urban runoff can be different from that in undeveloped areas. The details of this are very site specific, but in general one might expect increases in heavy metals, road salts, and organic materials associated with vehicle access and other urban activity. One might also expect changes in indicator bacteria levels and possibly pesticide, nutrient, and herbicide. Table 1.1 provides some indication of values which can be encountered in some parameters of interest.

Since runoff is not free of contaminants even under non-urban conditions, the degree of change in water quality depends on prior land use as well as on the form of urban development. Agricultural land use, for example, will represent a different initial condition than undeveloped forest areas or wetlands. Either way, there is a need to provide protection and mitigation of water quality degradation after development.

- urban land use changes pollutant sources
  - pesticides, herbicides may increase
  - nutrients may increase
  - indicator bacteria tend to increase
  - road salts and vehicle emissions increase
  - organic materials may increase
  - heavy metals increase
  - anthropogenic floatable materials may increase
- rainfall washes pollutants off catchment surface
- runoff contains increased contaminant loads

Typical Impacts of Urbanization on Water Quality

Stormwater management measures very often are targeted at water quality improvement. Measures which are used include:

- control of pollutant sources, by managing land use or land activity (such as fertilizer application)

- detention of runoff, by implementation of control ponds or other water quality management practices which encourages sedimentation and decay

- control of runoff discharge points, to manage impact locations

- use of the assimilative capacity of the receiving water to diffuse and accept tolerable amounts of some contaminants

The hydrologic analysis which is required for the assessment of stormwater quality facilities is substantially different from that of the quantity facilities since chemical, physical, and biological reactions must be incorporated.

Table 1.1. A Few Representative Urban Stormwater Pollutant Constituent Concentrations.

Parameter	USEPA[1]	E.Yrk[2]	St.Cat[3]	King[4]	Ont[5]
Total Suspended Solids (mg/L)	125	281	250	72	25
Biological Oxygen Demand(mg/L)	12	14	8.2	8.5	/
Chemical Oxygen Demand (mg/L)	80	138	/	/	/
Total Phosphorus (mg/L)	0.41	0.48	0.33	/	0.03
Soluble Phosphorus (mg/L)	0.15	0.06	0.084	0.118	/
Total Kjeldahl Nitrogen (mg/L)	2.00	2.20	0.89	/	/
Nitrate and Nitrite (mg/L)	0.90	0.46	0.65	0.25	/
Total Copper (mg/L)	0.040	0.050	0.021	0.009	0.005
Total Lead (mg/L)	0.165	0.570	0.084	0.013	0.025
Total Zinc (mg/L)	0.210	0.330	0.100	0.064	0.030
Fecal Coliform (No./100ml)	21,000	11,000	68,000	21,000	100

1. U.S. EPA - Mean concentration for median urban site Nationwide Urban Runoff Program (NURP) (Driscoll & Mangarella, 1990)
\- Fecal coliform, Median Event Mean Concentration (EMC), 11 sites (NURP, U.S. EPA, 1983)
2. East York - Arithmetic mean, 18 events, 1 site (Kronis, 1982)
3. St. Catharines - Geometric mean, 4 events, 1 site (SCAPCP, 1990)
4. Kingston - Geometric mean, 8 events, 1 site (CH2M Hill, 1990)
5. Ontario - Provincial Objective or Guideline, MOEE or MNR)

1.2.5 Impacts on Stream Morphology

The stream form is determined as the net result of applied load (flow and sediment), and native materials (bank and bed), as affected by urbanization, over time. The stream will tend to erode or aggrade if the natural balance of these factors is altered. It should be recognized that a natural channel does exhibit some variability in any case, since the balance is not static, but is a dynamic interaction that reflects changing seasons, precipitation patterns, and other factors. However, if that dynamic stability is altered, the system will react, and change, until a new stable regime is formed.

- upstream flow and sediment loads are altered
- sections of the stream may be channelised or re-aligned
- flow velocity and depth may change locally, so
- sediment carrying capacity changes, and erosion or deposition occurs, causing
- instability and change in channel form, until
- a new stable form is (eventually perhaps) reached

Typical Impacts of Urbanization on Stream Channel Stability

The impacts of such a change can be numerous, and include channel re-alignment, bank undercutting or instability, and changes in sediment bed load. These changes, aside from their hydraulic consequences, can have a significant impact on the habitat which is available for terrestrial and aquatic populations.

Stormwater management measures which are available to control or moderate changes in stream morphology include:

- placement of structures or other hydraulic controls to affect instream flow rates, energy, and transport potential,

- control of runoff rates using control ponds or other devices so that acceptable transport energies (velocity, depth etc.) are maintained instream, and

- control of runoff volumes by means of suitable stormwater best management practices (BMPs), so that volumes and long term rates of flow are maintained at acceptable levels instream

1.2.6 Impacts on Stream Habitat

The habitat offered by the river system can be affected by urban stormwater in a number of ways. The cumulative effect of water quality changes and flow changes, including possible alterations of the stream morphology, are all potentially important in determining stream habitat. Some important considerations are temperature and water quality, which have a bearing on the value of the resource as a cool water or warm water fishery; dissolved oxygen, which affects the ability of the water to support fish; nutrients which affect trophic status; bedforms, substrate, velocity and depth, all of which affect the suitability of the location for particular species; barriers to fish migration and/or mobility, including jumps or falls, which may result from shifts in the flow rate or channel form; and, contaminants, which may eliminate the stream as a habitat site altogether.

- numerous urban impacts on stormwater affect flows, quality, channel form and result in
    - altered substrate
    - change in base flow regime, altering pools, ripples and other governing stream flow features
    - degraded quality and increased temperature
    - change in trophic status (abundance of weeds, algae etc)
    - change (increase) in sediment load

- these factors govern habitat suitability for existing or any other population
- if habitat suitability changes, the whole ecosystem may change

Typical Impacts of Urbanization on Stream Habitat

The stormwater management measures which are appropriate in the management of these various features are combinations of the measures described above, as they affect water quality, stream morphology, flow rate, and so on.

1.3 SOLUTIONS TO STORMWATER MANAGEMENT ISSUES

The above sections deal in general terms with the types of stormwater measures which are appropriate as responses to parts of environmental protection, and later Chapters will deal with specific management practices in detail.

As indicated above, understanding has led to new practice, including stormwater management measures designed to reduce the impact of development and hence the need for costly remediation after the fact.

Another complexity arises from the large number of diverse factors in the problem, some of which are only partly defined. This can make selection of the solution difficult. If trade-offs occur between various alternatives, for example in the relative merits of habitat enhancement at one point in a stream versus another, there is no recognised means of making a choice. Subjective judgement, supported by some quantitative information and analysis, becomes the basis for the plan, in turn becomes the solution.

The net result is that derivation of solutions must at present be based on the interpretation and evaluation of a diverse variety of pieces of information. The systematic identification of critical requirements for control, based on an identified vision of the developed watershed, must be the starting point for stormwater management.

The Vision

The solution of the stormwater management problems begins with a vision of the watershed, developed as the result of concerted interaction between stakeholders that includes the public, regulators, developers, and other parties to the decision.

The Criteria

Based on the vision for the watershed, the various elements of the problem can be put into perspective. Key decision elements are identified, and the relative importance of criteria is then known.

The Strategy

Based on opportunities and constraints that physically govern the watershed, various strategies are then evaluated. A strategy includes development scenarios, control measures, and environmental impacts that will be encountered as those measures and developments are implemented.

The steps in planning which follow the above process are fully described elsewhere in this series of Chapters. At this point, it is important to realise that *stormwater management is accomplished as an integrated plan that achieves specific identified goals on a watershed basis.* It is not a device, a control measure, or a single criterion.

CHAPTER 2

WATER MANAGEMENT
ON
A WATERSHED BASIS

CHAPTER 2

2.1 INTRODUCTION

Much of the material presented in this module was obtained from the MOEE/MNR document entitled "Water Management on a Watershed Basis:Implementing an Ecosystem Approach", June 1993.

2.1.1 Training Objectives

The goal of Chapter 2 is to provide an overview of the development and implementation of a "Watershed Management Plan". To put watershed planning in perspective, watershed issues, goals and objectives are discussed and an overview of the land use planning process is provided.

The specific training objectives are to develop an understanding of the following:

1. The ecosystem approach to water management.

2. The relationship between, and importance of, Watershed Plans, Subwatershed Plans, and Site Management Plans.

3. The need to integrate watershed management into the Official Plan through the land use planning process.

4. The essential components of watershed plan development and implementation.

2.1.2 Background

The term "ecosystem" refers to the physical environment such as air, land, water, and the biological elements such as living organisms, and the interactions among them.

Water moving through the global hydrologic cycle falls to earth and drains from the land transporting dissolved and solid materials from the land to the surface water and/or to ground water, as illustrated in Figure 2-1. This drainage water and these materials modify the physical, chemical and biological characteristics of streams and lakes. A **water ecosystem**, therefore, includes all water, whether flowing or standing, the processes, factors and natural cycles which affect it and the organisms which live in the water and depend on it. A *watershed* is comprised of the land drained by a river and its tributaries. A *subwatershed* is comprised of the land drained by an individual tributary to the main watercourse. A watershed is a discrete ecosystem, the state of which is affected by the environmental condition of its component subwatersheds and by the condition of the mainstem river. The boundary of a watershed provide the natural limits for managing the interconnections between human activities and a water ecosystem.

The environment and resources contained within a watershed are managed to preserve the natural values important to our society and to ensure that our continued use of them is sustainable. In the case of water, these include a healthy aquatic ecosystem, adequate supply, and water that is contaminant-free.

With an emphasis on the protection of the form and function of the natural environment, it is no longer acceptable, from an environmental as well as economic perspective, to impair water quality, degrade aquatic/terrestrial habitats, reduce baseflows, lower ground water tables, drain and sewer large areas, or line watercourses with concrete to the point where the integrity of the natural system is lost.

Municipalities have the legislative authority and political responsibility to undertake comprehensive land use planning which considers environmental issues. A consensus is emerging that land use planning does not always satisfactorily protect the environment, particularly from the negative cumulative environmental effects of changing land uses.

An ecosystem approach to land use planning provides early and systematic guidance on the interrelationships between existing and potential land uses and the health of ecosystems over time. This approach is based on the recognition that **ecosystems have limits to the stress which can be accommodated before the ecosystems are irreversibly degraded or destroyed.** Furthermore, this approach requires that environmental goals be treated equally with and be considered at the same time as economic and social goals.

When ecosystem considerations are integrated into the planning process, it is more likely that land use decisions will not jeopardize ecosystem and human health. Furthermore, an ecosystem approach can result in economic savings by avoiding the need for costly and difficult remedial actions.

The primary boundary for an ecosystem approach to land use planning should be the watershed. This is based on using the hydrologic cycle as the pathway that integrates physical, chemical and biological processes of the ecosystem. An appropriate vehicle for this integration is the watershed management plan. By providing a broad understanding of ecosystem function and status, and recommending actions for appropriate resource management in the watershed, the watershed plan can "capture" relevant ecosystem considerations that can be integrated into land use planning and decisions.

FIGURE 2-1. The Water Cycle.

2.1.3 Overview

This Module is organized into 3 sections which are summarized below:

1. Watershed Plans

   This section provides a general discussion of watershed goals and objectives. Included in this discussion is a presentation of relevant planning documents such as the Watershed Management Plan, Subwatershed Management Plan, and the Site Management Plan.

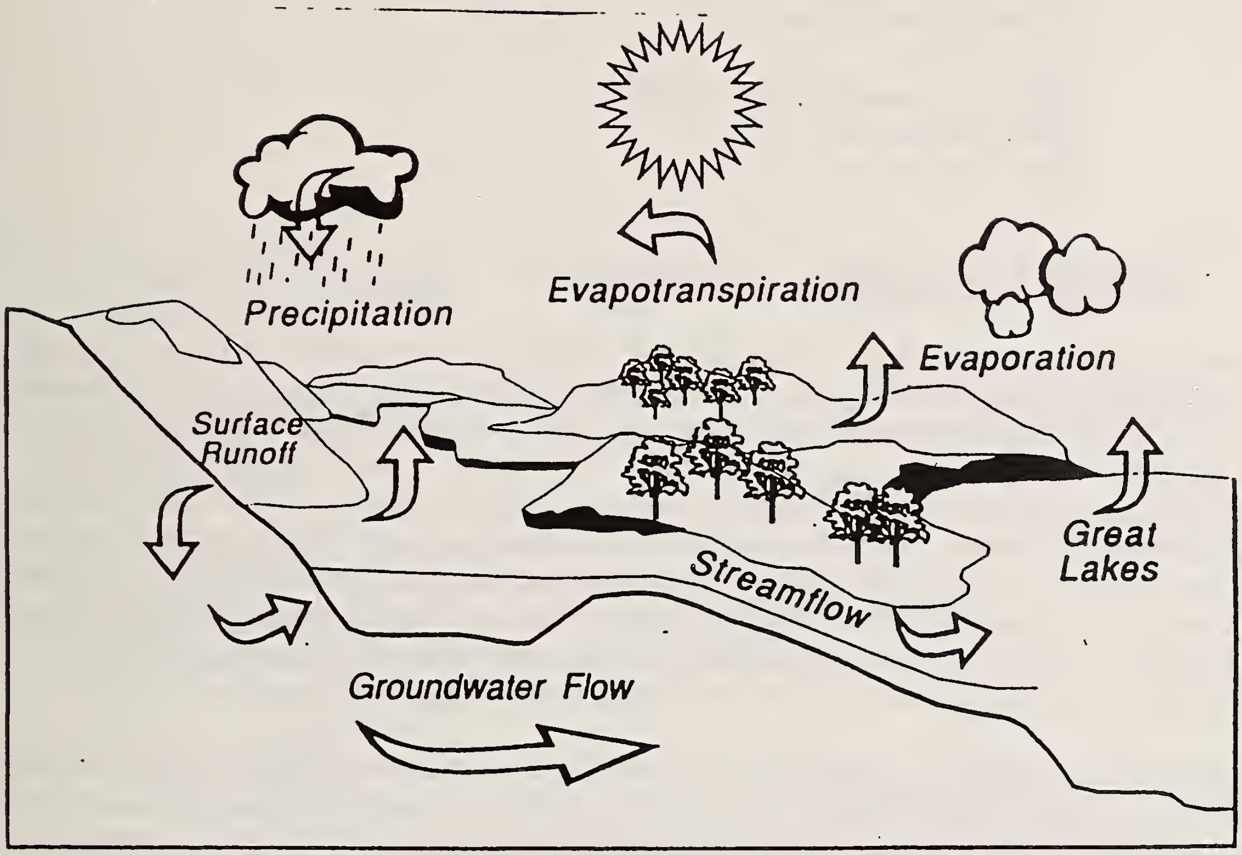

Figure 2-1 *The Water Cycle*

2. Land Use Planning Overview

This section provides a brief overview of land use planning in the municipal context.

3. Watershed Plan Development and Implementation

The final section provides a discussion of watershed planning which includes:
- the planning framework
- the plan development
- roles and responsibilities
- plan funding
- performance monitoring of the plan
- keeping the plan up-to-date
- public participation.

<u>*2.2 WATERSHED PLANS*</u>

A *Watershed Management Plan* is a document developed cooperatively by government agencies and other stakeholders to manage the water, land/water interactions, aquatic life and aquatic resources within a particular watershed. It recommends how water resources are to be protected and enhanced in relation to changing land uses. In so doing, it also "sets the stage" for the undertaking of smaller scale subwatershed management plans (Figure 2-2). A *Subwatershed Management Plan* should reflect the goals of the watershed management plan but is tailored to tributary needs and local issues (Figure 2-3). Subwatershed plans can provide more detailed guidance for site-specific water resource planning issues. Further detail on subwatershed planning can be found in a companion module, *Subwatershed Planning*. Finally, localized, site-specific planning is provided for in *Site Management Plans* (Figure 2-4).

On the basis of ecological mapping of a watershed, a watershed management plan ascribes sensitivity ratings to natural values, and prioritizes them, and then identifies selected areas for preservation, protection, enhancement or rehabilitation. The plan should also provide an "image" of how the watershed should look and function, and what areas are appropriate for preservation, protection, enhancement or rehabilitation of desired values. This "picture" can be portrayed in terms of ecological areas, e.g., headwaters, middle reach, mouth/delta/estuary, etc.

The plan is a "blueprint" for responsible water management and water-based resource management, and a guideline for the execution of civic responsibilities and provincial mandates. A watershed plan covers a broad area in size and a wide range of environmental topics. *Its focus, however, is water and water resource-related issues.* The plan purposely lacks the detail and specific information needed to describe local conditions or address local issues. Rather, a watershed plan provides a comprehensive understanding of ecological form and function in the watershed, an understanding of water and water-related functions across time and space.

Watershed Plans → Subwatershed Plans → Site Management Plans

- will take a broad ecosystem approach to water, water related natural features, terrestrial resources, fisheries, water dependencies/linkages and valley/open space systems

- will provide watershed-wide policy and direction for:
  - ecological integrity and carrying capacity
  - the protection of valley systems and green space planning
  - the management of water quantity and quality
  - aquifer and ground water management
  - fisheries management
  - rehabilitation/enhancement programs
  - a framework for implementation of watershed policies and programs
  - regional opportunities/constraints
  - document servicing needs/availability of water/sewerage

- will delineate subwatershed planning areas
- present targets, goals and objectives for subwatershed

PLAN RECOMMENDATIONS TO BE INPUT TO OFFICIAL PLANS

Figure 2-2 *Watershed Plans*

Watershed Plans → **Subwatershed Plans** → Site Management Plans

- enhanced detail to address local environmental issues
- will detail and implement specific subwatershed targets, goals, objectives to establish:
  - natural system linkages and functions
  - surface and ground water quantity and quality management
  - the enhancement, rehabilitation of natural features
  - areas suitable for development
  - best management practices for incorporation into subdivision designs
  - specific implementation schemes and responsibilities for all recommendations
  - management practices for open space areas and green space corridors
  - an implementation strategy
- will outline directives for stormwater management plans and other studies/designs for specific areas within the subwatershed
- future monitoring requirements will be outlined

PLAN RECOMMENDATIONS TO BE INCORPORATED WITH OFFICIAL PLAN AMENDMENTS

Figure 2-3 *Subwatershed Plans*

Watershed Plans → Subwatershed Plans → **Site Management Plans**

- will present the designs of specific best management practices, subdivision drainage designs, details of enhancement or rehabilitation programs
- will demonstrate compatibility of designs with subwatershed plan recommendations
- may include permits and applications for construction approvals
- may include requests for clearance of draft plan conditions
- may indentify need for specific environmental assessments
- may detail design, operation and maintenance of Stormwater Best Management Practices

PLAN RECOMMENDATIONS TO ASSIST WITH PREPARATION OF PLANS OF SUBDIVISION AND LAND/RESOURCE DEVELOPMENT PROPOSALS

Figure 2-4 *Site Management Plans*

Plans are also drafted for co-ownership, for partnerships. Water management and land use planning issues in an entire watershed necessarily affect a range of jurisdictions and stakeholders: municipalities, conservation authorities, the Ministries of Environment and Energy, Natural Resources, Municipal Affairs, and Agriculture and Food and other local stakeholder agencies.

The watershed plan can also provide very specific directives for subwatershed studies, including identification of the subwatersheds, priority ranking of subwatersheds, and subwatershed issues and goals. A watershed plan provides a view of the landscape as a nested hierarchy of drainage basins. As such, it can narrow the set of variables or directives needed for effective decision-making at lower levels. This can assist decision-makers as to the appropriate level of resolution required, or to identify comparable situations elsewhere in the watershed. For example, wetlands, or deep/shallow aquifers can have different significance if they are considered on a watershed or subwatershed basis.

A watershed plan can provide a range of practical, environmentally acceptable and economically sound recommendations at a time when they can be effectively incorporated into land use planning documents and decisions. Watershed planning can enable decision-makers to accommodate both land use and ecosystem needs. It also allows water managers to focus on water issues and water-based resources in the context of other ecosystem issues. It allows land use planners to make better decisions about appropriate land uses.

By inviting, and requiring for its success, the participation of a wide range of stakeholders and jurisdictions, watershed planning encourages co-operation, information sharing and coordinated efforts. This alone can boost the efficiency of planning (less duplication, overlaps, delays, information gaps), and therefore, reduce the cost of planning for these stakeholders.

In practical terms, if all participants have been continually fully involved in the evolution of the plan, there is greater likelihood that, when it is completed, everyone will be relatively satisfied and therefore committed to it, and will know what their responsibilities are for implementing it within their own jurisdictions and mandates.

Public awareness of and participation in the plan is a key determinant of its success. Since public inputs are considered in the development of plan, the community will be receptive to the decisions that are made regarding the development and management of the resources in the watershed. In a well conceived plan there are economic and ecological benefits which are of value to the community and to society as a whole. These include:

- significant sensitive natural resources and environments;
- recreational opportunities;
- new development that respects ecosystem integrity;
- water taking/water use assessment;
- hazard land designation; and
- efficient servicing.

Public involvement has significant benefits. For example, public involvement in plan development increases the likelihood of public understanding of and support for the plan. This support translates directly into stakeholder willingness to advance the plan, fund plan implementation, and to carry out their mandates/responsibilities in accordance with the plan.

The watershed planning process begins with a description of the end in mind. Goals of the watershed plan provide a statement of how the watershed should be developed and managed. They address local watershed management issues and needs. Initially, broad "goals" will have been formulated to guide and limit the gathering of information on biophysical conditions in the watershed. On the basis of the information collected, and the issues identified in the watershed, goals for watershed management can now be formulated with greater understanding and certainty.

Goals are developed for features of the watershed that are desired values, or threats to desired values, e.g., water quality, ground water, recreation, aquatic communities, flood protection, erosion control, natural features and aesthetics. Within each area of the watershed, management goals should be stated for each management category: preservation/protection, rehabilitation, enhancement. This provides focus for subsequent management actions.

Because the cost and effectiveness of the watershed plan and subsequent land use decisions are entirely dependent on the quality of the goals themselves, management goals should be carefully thought out, clear, and precise.

Goals should be defensible, that is, supported by sound ecological and economic reasoning. They should also be sufficiently flexible to accommodate natural fluctuations in watershed conditions, and those for rehabilitation should be progressive and allow for future adjustments. Briefly, management goals should:

- be easily refined as new information becomes available
- be practical to ensure achievability;
- be explicit, verifiable;
- be result focused to ensure accountability of those implementing the plan;
- have public/agency/stakeholder endorsement; and
- be economically responsible.

Also, goals for the watershed provide the focus for the formulation of subwatershed goals. It is also appropriate for the watershed plan to identify its component subwatersheds, key issues in those, and some general suggested management strategies and priorities for action.

Each watershed and ground water aquifer system in the province exhibits unique conditions and is subject to particular pressures. It is important, therefore, to establish goals and objectives that address the water and related resource management issues *that are particular to that individual watershed and ground water aquifer system*. These goals and objectives are formulated on the basis of the following accepted watershed planning and management principles.

PRINCIPLE #1. The Watershed and the Hydrologic Cycle as the Basis for Planning and Management

The watershed and subwatershed basins and the hydrologic cycle are the basis on which watershed systems are planned and managed to meet water management objectives. Where possible, the impact of land use changes or proposed developments will be evaluated on the basis of their impacts

on the watershed, subwatershed, and aquifer system, including upstream/downstream and cumulative effects of these changes.

PRINCIPLE #2. Stream and Lake Conditions

Changes to natural vegetation and natural processes in watersheds and subwatersheds have resulted in detrimental changes to stream and lake conditions. These changes have impacts on runoff, temperature, habitat, chemical and baseflow characteristics which adversely affect natural aquatic communities.

PRINCIPLE #3. Maintaining Natural Watercourses

All land use and natural resource management activities should maintain watershed systems such as headwater streams, watercourses, lakes and related riparian systems in a naturally functional and as undisturbed a state as possible.

PRINCIPLE #4. Valuing the Resource

In making decisions about the treatment or removal of water from a site, the proponent should consider this water to be a valuable natural resource to be properly managed, rather than a by-product of land use changes.

PRINCIPLE #5. Best Management Practice

Best Management Practice (BMP) involves an attitude to the resource, a willingness to consider aspects of its welfare, as well as the best technology to accomplish this, where available. The best available technology economically achievable should be used to manage water resources in a way that maintains, and where possible enhances, the health of watershed systems.

PRINCIPLE #6. Innovative Approaches

Planning agencies and proponents of development should be encouraged to explore innovative approaches to better address water management needs on an ecosystem basis.

2.3 LAND USE PLANNING OVERVIEW

In the municipal land use planning process, the key planning document is the official plan. The official plan sets the municipality's goals and objectives for land uses within its jurisdiction. The official plan also provides specific policy direction which guides land development in accordance with provincial policies and guidelines as provided for under the *Planning Act*. *It is an important mechanism, therefore, that can be used to promote and implement the objectives of water and related resource planning. If this is done, the process can be considered to be integrated land use/ water resource municipal planning.*

The policies of the official plan should clearly recognize the importance of the quality of surface water and related resources to the environmental, social and economic well being of the municipality.

Under the *Planning Act*, the municipal land use planning process sets out a distinct framework for the development of environmental, social and economic goals and objectives for the municipality. However, the planning process alone cannot be expected to incorporate and implement all aspects of an effective watershed planning and management process. Therefore, linkages between the two processes are very important.

Watershed planning is recognized by federal and provincial governments as being the most effective means of evaluating and developing water-related resource management strategies and practices. Most decisions that are made on privately owned lands, however, are made in the context of the municipal land use planning process on the basis of municipal boundaries or property ownership. It is very important, therefore, that there be adequate linkages established to incorporate water and related resource management directions into the municipal land use planning process.

Because land use planning can be influenced by environmental issues beyond the boundaries of particular upper or lower tier municipality, it is important that these municipalities incorporate the input of agencies mandated to manage broader water and related resource management areas. Upper tier plans (e.g. Official Plans of Regions, Counties, etc.), can provide for implementation of provincial policy and resource and growth management by means of a strategic, coordinated approach to physical (land use), social and economic development.

Each municipal level, both upper and lower tier, need to integrate water management components into the municipal planning process. This integration provides policies and directions for the protection of aquatic resources, as well as providing a better information base for traditional planning decisions.

Upper tier official plans provide for the coordination and management of resources at a regional level. Because of wide geographical context, the plans should:

- establish the broad land use strategy for the region or county,
- outline provincial interests and programs in municipal terms, and
- provide a basis for allocating the area's resources among member municipalities and among various population concentrations in accordance with the goals and objectives it sets out.

Lower tier plans address community needs in conformity with the broad strategic framework of the upper tier plan, but at a local, detailed level. In this way, both upper and lower tier plans can have a long-term horizon, but at different levels of detail, and different geographic perspectives. The coordination of upper and lower tier plans provides a unique opportunity for the development of a strategic and multidisciplinary approach to land use planning.

2.4 WATERSHED PLAN DEVELOPMENT AND IMPLEMENTATION

The ultimate goal of watershed plan development and implementation is to see that the appropriate components developed through the watershed planning and management process are incorporated and/or linked into the municipal planning process, as highlighted in Figure 2-5.

The official plan should identify implementation schedules and mechanisms, that is, how and when the policies in the official plan will be implemented. This includes, for example, identifying when specific water and related resource planning and management tools, like subwatershed plans and stormwater management plans, will be needed. This is to ensure that linkages between watershed and land use planning are established at the outset. These policies should be implemented through zoning by-laws.

Where a watershed plan has been prepared, all land use planning decisions should be carried out in accordance with the recommendations of the watershed management plan. An official plan can reflect the broad directions, goals and targets established in the watershed management plan.

2.4.1 Planning Framework

Before embarking on the development of a watershed plan, participants are advised to follow some important steps for organizing and managing that process. The process itself can be divided into three main stages: (1) set the stage, (2) prepare the plan, and (3) adopt the plan.

Stage 1. Set the Stage

Initially a number of events or actions have made it apparent to agencies such as conservation authorities, provincial agencies and local governments that there is a need for a watershed plan. These events could be such things as land use conflicts and degraded environments. The challenge is to transform requests for a watershed plan into commitments for participation, support, adoption and implementation of the plan. One of the most significant jobs in these early days is to prioritize issues to which resources need to be directed.

A need having been established, the next step is to identify the main issues and concerns in the watershed which have brought the parties together to try to formulate a watershed plan. In almost all cases, there should be sufficient information to draft a brief overview document outlining the presence and status of water and water-related features as well as aquifer resources. At this point, the planners need not be concerned about overlooking issues or concerns that may prove important at a later stage; these issues will be more firmly established as plan development progresses and as more information becomes available.

Watershed and Municipal Planning

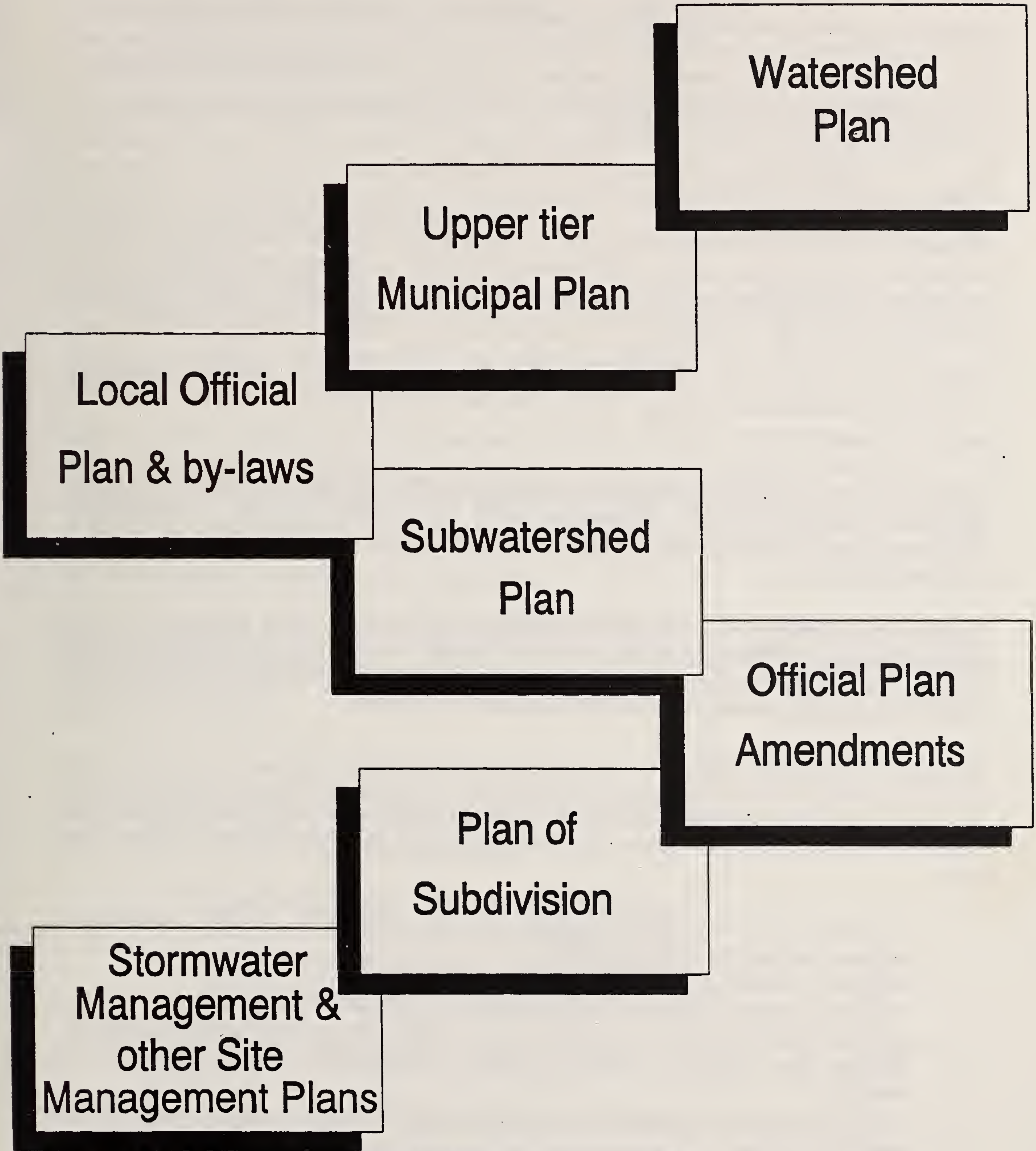

Figure 2-5 *Watershed and Municipal Planning Process*

While conservation authorities are an obvious choice for coordinating the preparation of a watershed plan, other agencies may also be considered for this role, e.g., local municipality, MOEE and MNR. The latter will certainly be necessary for areas of the province outside conservation authority and/or municipal jurisdiction (e.g. regional groundwater systems).

Determining funding requirements and responsibilities is an important and challenging task in this early part of the planning process. The parties need to know the extent of funding that will likely be required, possible sources of funding, the extent to which each party can contribute, and possibilities for phasing the undertaking. All these factors influence the framework for initiating the watershed planning exercise.

Stage 2. Prepare the Plan

Representatives from the core provincial agencies, along with First Nations within the watershed, members of public interest groups, agricultural communities, and local municipalities may be appropriate representatives on a Steering Committee to coordinate plan development activities. Membership could also be extended to other parties later at certain key decision points.

While it might seem obvious, the Steering Committee should confirm or redefine the watershed boundaries for the planning exercise. This may include consideration of important ground water recharge and aquifer areas.

At this point, broad goals for watershed management can be formulated, to be refined as more information becomes available. These goals need to be agreed upon by all participants. Discussions should begin on ways of securing <u>early</u> and <u>continued</u> involvement of the public in plan development.

As part of plan preparation, it is important at this point to prepare a Terms of Reference for the watershed plan development exercise, which will clearly identify the work program, project schedule, and expected products. A key consideration in drafting the Terms of Reference is that only the information essential for plan development be collected.

Stage 3. Adopt the Plan

In large measure, the ease with which the final plan is adopted by the participating agencies will depend on the effectiveness of the preceding stages in the process of developing it. These stages are:

- work out and agree upon the questions of goals, affordability, benefits, suitability of proposed actions, and responsibilities;
- establish evaluation criteria and the assessment protocol;
- collect all relevant background information and supplementary field data;
- screen all possible BMP measures for a set of feasible and practical BMP techniques;
- combine these measures together in various combinations to form alternate SWM strategies;
- apply the assessment protocol to the long list of strategies to select a recommended strategy(ies); and,
- verify the utility of the recommended strategy against the evaluation criteria.

When all participants agree on a final direction, the recommended strategy can be adopted as the SWM Plan and the real work of watershed management can begin. Conversely, little will be achieved if there is no such agreement. Because after this point, the responsibilities for implementation and provision of operating costs now fall to participating agencies. At this point, commitment to implement the plan is secured from all participants.

2.4.2 Information Gathering

A great deal of information about the target watershed is required for the watershed management planning process. At the outset, the planners need to know what conditions exist in the watershed, and what issues are of significance, in order to determine appropriate goals for the watershed. The primary purpose of information gathering is to secure an understanding of ecological form and function in the watershed.

A successful and acceptable watershed plan need not collect extraordinary amounts of information on the watershed ecosystem. The planners, in conjunction with the technical resource experts, need to determine what information is needed to meet the planning and management needs of that watershed. This means what <u>kind</u> of information and <u>at what level of detail</u>.

Before this can be done, the planning team needs to know, in broad terms, what they are looking for. They can limit information gathering on the basis of a <u>realistic</u> assessment of the biophysical information on the watershed required to formulate <u>realistic</u> goals. This is not really a tall order. The planning team by this point should be able to formulate broad-based "goals" for watershed management. This is in advance of the intensive information-gathering exercise on the biophysical conditions in the watershed.

Next, an important exercise for the planning team is to determine what information is already available, and what must still be collected. Much valuable information exists in previous watershed studies and as a result of provincial agency activities; it is recommended that these sources be consulted.

If it is determined that further information is required for a proper picture of the watershed, the following questions may provide useful criteria for limiting the scope of information gathering:

- What information is <u>really</u> needed to:
  - improve knowledge of the watershed ecosystem?
  - further refine the watershed management goals?
  - ascertain management practices that will be effective?
  - define and prioritize subwatersheds?

- To what extent could decisions be made better by what improvements in the information available?

- How might information be improved through different types of monitoring and studies? What are the costs and time required for such studies?

This is an important exercise. Scoping or focusing the information-gathering required can significantly reduce the costs of plan development. It can lead to a better plan because all the information is relevant to the formulation of goals for the watershed. All this can result in more efficient management and thus less cost later.

Some sources of watershed information include:

- watershed municipalities
- the watershed conservation authority
- provincial/federal government agencies
- Crown agencies, e.g., Ontario Hydro
- Ontario universities and colleges
- private interest groups
- private companies

Typical kinds of information include:

- provincial and federal mapping
- technical reports
- municipal official plans
- pollution control reports
- impact studies
- remote sensing information
- physiography texts
- wildlife/fisheries inventories and information
- other resource inventory reports

Initially, information is needed on the structural and functional relationships among air, land and water and associated biota of the watershed ecosystem over time. This consists of a summary of environmental features such as natural features, aquatic communities, water resources including water quality and ground water, recreational areas, flooding, erosion and aesthetics.

The most practical and useful way to obtain this information is to carry out "ecological mapping." The technical information and the level of detail required to ecologically map a watershed, and to evaluate sensitivities will reflect the management goals for that watershed and the sorts of land use change impacts anticipated.

Information on water resources, could include:

- maps showing the watershed location and watershed boundaries (surface water and ground water)
- maps showing subwatershed locations and boundaries
- water quality assessments for the mainstem river and tributaries
- land use patterns
- hydrogeology
  - ground water/aquifer
  - well location maps
  - direction of ground water movement/relative transmissivity

- recharge zones/susceptibility to contamination
- ground water spring locations
- floodline maps

Information on biota could include:

- ecological surveys and biological inventories
  - fish habitat, e.g., spawning and rearing areas, migratory routes, etc.
  - Ministry of Natural Resources District Fisheries Management Plans
  - vegetation, e.g., MNR forest inventory maps
  - migratory water bird habitat information/wetlands
  - earlier river basin and watershed studies of the area
  - wetlands, Areas of Natural or Scientific Interests (ANSIs), Environmentally Sensitive Areas (ESAs)

Information on water uses, e.g., recreational impoundments, aquaculture, and hydroelectric, could include present and potential sources of point and non-point contaminants such as:

- storm sewer outlets
- sanitary sewer overflows and cross-connections
- industrial effluent outlets
- areas of direct livestock access
- septic tank systems
- milk house wastes

Ecological boundaries should be depicted as encompassing areas which possess similarities and/or areas which are interdependent. Ecological boundaries of importance for management should be derived from:

- the watershed management goals
- watershed issues
- knowledge of aquatic ecological relationships

Where ecological boundaries extend beyond the watershed, information should be collected in cooperation with adjacent conservation authorities and municipalities.

2.4.3 Development of Plan

The alternatives and evaluation phase of plan development considers alternative measures that may be used to protect, enhance or rehabilitate the environmental features identified in the watershed issues and goals.

A watershed plan represents a strategic planning exercise whose intent is to maximize benefits to the watershed as a whole, and to minimize the efforts and costs needed to formulate planning decisions and put directives in place.

A key part of this strategic planning exercise is to consider alternatives -- alternative approaches,

alternative scenarios, alternative measures. It needs to explore what is needed to achieve the goals. These considerations include costs, affordability, public acceptance, timing, legitimacy, feasibility, likely effectiveness, and the degree of ease or difficulty of implementing certain measures.

Before alternative scenarios are considered for various resource features, for example, different general approaches to resource management can be identified as possible courses of action, including: pollution prevention, pollution control, regulatory control, land use policy/planning, water conservation, and habitat enhancement.

Recommended actions are the result of the multi-objective evaluation of watershed conditions and issues relative to goals by means of management scenarios with alternative actions. At this point, there should be a fairly clear notion of what actions are needed to meet management goals and objectives in each part of the watershed.

The watershed management plan should set out recommended actions for each ecological area in the watershed in terms of management categories: prevention/protection, enhancement, and rehabilitation.

- <u>Protection</u>: The ecologic areas include headwaters, aquifer recharge/discharge areas, wetlands, and fish habitat. To promote ecosystem protection, appropriate initiatives should be developed for key water and water-based elements that are necessary for protecting ecosystem health.

- <u>Enhancement</u>: The plan should specify opportunities for **enhancement** of ecological components and particular uses that will serve to improve the function and health of the ecosystems, such as, infiltration, vegetative linkages, buffers, fish habitat, sanctuaries, public access points, treed parks, creation of rural beaches/water contact sport areas, and riparian vegetation.

- <u>Rehabilitation</u>: Criteria for prioritizing site rehabilitation should be established, and time and fiscal and human resources required for each site should be estimated. The plan can outline preferred measures or strategies for improved land management and for the abatement of all point and non-point sources.

Natural resource managers can take advantage of overlaps and interrelationships among categories of management goals to maximize the use of available fiscal and human resources. For example, a **preserve/protect** action might be aimed at maintaining ground water discharge characteristics and habitat quality for an existing brook trout population; an **enhancement** initiative might be aimed at constructing five brook trout spawning areas; a **rehabilitation** action could be aimed at restoring 10 kilometres of lost brook trout habitat.

Finally, the plan should provide a description of how environmental monitoring should be used to measure the success of watershed management decisions or actions.

2.4.4 Roles and Responsibilities

The scheduled events and responsibilities for implementing the recommended actions are a

delivery mechanism that should provide answers to the questions:

- **what** doable tasks are needed to accomplish each recommended action?

- **who** is accountable for each task?

- by **when** is each task to be accomplished?

- **how** will monitoring results be used to modify implementation?

Implementation of recommended actions is likely to take place largely through land use planning decisions, but others will be the responsibility of participating agencies, through such things as approval processes, regulations and permits. If there has been consistent interaction among participating agencies throughout the plan development process, it is likely that by the implementation stage, all participants will know what they are required to do.

The issues and recommended actions in watershed plans involve the jurisdictions and mandates of a range of agencies, including municipalities, conservation authorities, provincial ministries, First Nations and private interests. All participants can effectively use existing mechanisms and tools, such as legislation, policies, procedures and approval processes, to implement the watershed plan. Provincial agencies such as MOEE, MNR, MMA, and OMAF have a number of key pieces of legislation that can be used to carry out recommended actions. These include MNR's *Lakes and Rivers Improvement Act, Endangered Species Act, Trees Act,* and *Provincial Parks Act.* Also useful are MOEE's *Environmental Protection Act, Environmental Assessment Act,* and *Ontario Water Resources Act,* as well as OMAF's *Drainage Act.* A listing of provincial legislation is available in <u>Ministerial Responsibility for Acts</u>, Ministry of Government Services, Queen's Printer for Ontario, 1991. The federal *Fisheries Act* is also applicable.

Conservation authorities are encouraged to administer the provisions of the *Conservation Authorities Act,* and Fill, Construction and Alteration to Waterways regulations pursuant to Section 28 of the Act. Municipalities are encouraged to administer the provisions of the *Municipal Act* and the *Planning Act* and plans and by-laws adopted according to these acts.

Conservation authorities, where they exist, are encouraged to coordinate watershed management, and can play a key role in plan implementation by:

- Assisting municipalities and planning boards to incorporate the intent and recommendations of the watershed plan into the land use planning process and appropriate planning documents.

- Reviewing proposed planning that may have implications for the watershed plan or water management.

- Assisting the Ontario Municipal Board or other appeal bodies, where a matter related to the watershed plan and water management may be an issue.

- Consulting with ministries, public agencies, boards, authorities and municipalities on matters pertaining to the watershed plan and water management, as appropriate.

- Informing the general public about the principles and practices of watershed management.

Where conservation authorities do not exist, the Ministry of Natural Resources and the Ministry of Environment and Energy are responsible for coordinating a program to address watershed planning and management.

2.4.5 Funding for the Task

Watershed plans vary widely in scope and kinds of activities required, and many jurisdictions and agencies are likely to be involved in this work. Thus, there cannot be a simple, generic funding formula in place. Those participating in plan development and implementation need to be innovative in securing new and various funding sources. Watershed studies to date have demonstrated innovative approaches to funding through the establishment of cost-sharing partnerships among agencies involved, and for funding some activities in phases. By phasing plan development or implementation, costs can be borne more realistically, on the basis of more precise information as the work progresses, and thus better cost estimates. Also, broad scope of watershed planning -- developers, local governments, provincial agencies, reviewers, landowners -- enhances opportunities for partnership funding.

It is possible for each of the participants to take part in funding the watershed plan by building their share of costs into their budgets for certain years, perhaps phased over several years with other partners. Participants may also find that some of their ongoing work can be "reprofiled" to contribute to the needs of the watershed plan. Participants are encouraged to make study costs "affordable" by a realistic scoping of study needs, and by innovative practices, such as phasing of study development, cooperative information sharing, assessment of previous work and trends to determine generic components or aspects of an acceptable watershed plan. **In any case, expensive long-term studies are not required to produce an acceptable watershed plan.**

2.4.6 Monitoring/Auditing the Success of Watershed Management

The relative success of watershed management decisions or actions should be audited using monitoring. Implementation of the plan should be a flexible and iterative process which both directs and responds to status changes in the adherence to recommendations and the achievement of the plan's goals. A monitoring program can identify the environmental conditions that indicate progress. There are two major components to monitoring: monitoring the success of the plan, achievement of its goals and objectives (response of the system to the implemented plan); and monitoring the performance and success of the tools used to achieve the objectives developed by the plan.

Implementing the watershed management plan will require monitoring data for a variety of uses. It is important to remember that **monitoring programs need not all be sophisticated or highly technical**. Sometimes, observation will suffice.

As well, it is important to note that **monitoring need only be applied to issues or conditions in the watershed that the plan has identified.** Furthermore, the plan can even identify some aspects to be monitored by federal or provincial agencies, as aspects to be incorporated into their ongoing state of the environment monitoring programs.

2.4.7 Currency: Keeping the Watershed Management Plan Up-to-Date

Effective watershed management is an iterative process, taking full advantage of both the successes and mistakes of implementation. Lessons learned from performance monitoring during implementation should be used to make appropriate revisions in watershed management programs.

As a general rule, it is appropriate to re-evaluate a watershed plan when land use changes are identified in an official plan of a municipality in the watershed.

Milestones for the progress of implementation are useful to keep implementation on track. Such milestones should also have some flexibility to allow for unusual or unforeseen circumstances, more efficient means of implementation, fiscal constraints, or fluctuations in natural environmental conditions. For the most part, however, adherence to such milestones as much as possible signifies commitment on the part of participants to act on recommendations in the plan.

2.4.8 Public Participation

The purpose of public participation in any planning or decision-making process is to allow for an exchange of ideas between the planning team and the stakeholders so that controversy can be minimized or avoided, and knowledge upon which good decisions are made can be improved. Increasingly, provincial and municipal agencies are recognizing that public participation in the development of plans or projects affecting the public is a key determinant of the success of these undertakings.

The real value of having the public play a part in planning watershed management is often overlooked. Interest groups and the public at large can provide valuable insights and information to any planning team, often bringing new ideas and a sound understanding of local conditions and aspirations. Drawing people into the planning process at an early stage can identify their concerns and interests <u>throughout</u> the process, and can provide "checks and balances" to the planning professionals.

An effective public participation program needs to identify and target a number of different audiences. Among those to consider are:

- **"Friends"** - people who are supportive of the planning effort and who are already "on board." These include local interest groups, environmentalists, groups that stand to benefit.

- **Affected parties** - individuals or groups who may be contributing to watershed degradation, but who also have a potentially important role in solutions. Examples include farmers, developers, boaters and foresters.

- **Local elected officials** - key decision-makers and opinion leaders who have an influential role in allowing a watershed planning effort to be accepted and implemented. They are usually interested in the political and financial implications of the planning process.

- **Government agencies** - officials and technical staff from a wide range of local, provincial and federal agencies, who can provide technical and political support to the planning effort. Other agencies include regional, township and city government agencies like public works, health, planning; special purpose agencies (interagency drainage boards, harbour commissions); federal agencies (Health and Welfare, Environment); and international agencies (International Joint Commission).

- **The "general public"** - this group is typically the target of any public participation effort. They are both environmentally aware and concerned, and keenly representative of their own interests and worries.

There is no single formula for designing an effective public education and participation program, but several key elements of any successful public participation strategy should be considered. Typical methods of reaching the public include: printed materials, special events, field trips, public meetings, media and public opinion polling.

Public involvement encourages local support for the project, and political endorsement of the project is likely to be easier if the public is in agreement with the project and its goals. Also, a supportive public can assist in making the project a reality and a success by monitoring the implementation of the project, its effects on local conditions, and its success in achieving the stated goals.

2.5 SUMMARY

A summary of the major topics covered by this training module is provided below:

1. Ecosystem Approach to Watershed Planning

   A watershed is a discrete ecosystem, the state of which is affected by the environmental condition of its component subwatersheds. The primary boundary for an ecosystem approach to land use planning is the watershed.

2. Watershed Planning Documents

   The goals of watershed management planning address areas or resources which are to be preserved, protected, or rehabilitated. These goals are incorporated into watershed planning documents such as the Watershed Management Plan, the Subwatershed Management Plan and the Site Management Plan. Each plan represents an increasing level of detail, however, watershed-wide goals and objectives are integrated into watershed planning at every stage.

3. Watershed Planning versus Land Use Planning

   At the municipal level, the key planning document is the Official Plan. The Official Plan represents an important mechanism to promote and implement the objectives of water and related resource planning.

4. Watershed Plan Development and Implementation

Important elements of watershed plan development and implementation are summarized below:

(i) Planning Framework: The framework of a watershed plan encompasses: (1) setting the stage, or establishing the need, (2) plan preparation, and (3) plan adoption or implementation.

(ii) Information Gathering: Careful assessment of existing information and efficient collection of additional information represent key elements of a successful Watershed Plan.

(iii) Development of Plan: The development of a watershed plan represents a strategic planning exercise designed to maximize benefits to the watershed as a whole. The plan sets out recommended actions for each ecological area in the watershed with regard to prevention/protection, enhancement, and rehabilitation.

(iv) Roles and Responsibilities: The issues and recommended actions defined in watershed plans involve a range of agencies, including municipalities, conservation authorities, provincial ministries, First Nations and private interests.

(v) Funding: Watershed planning is typically funded through cost-sharing partnerships among the agencies involved.

(vi) Monitoring: Straightforward monitoring programs are necessary to track the performance of a watershed management plan.

(vii) Currency: Lessons learned in performance monitoring are applied to make appropriate revisions to the watershed management plan.

(viii) Public Participation: Public involvement in the watershed management planning process is a key element to a successful water management plan.

Watershed management represents an effective means of preserving, or improving, the general health of a watershed ecosystem. Numerous benefits are realized by all parties concerned.

CHAPTER 3

SUBWATERSHED PLANNING

CHAPTER 3

3.1 DEFINITION AND RELATIONSHIP TO WATERSHED PLANNING

The Evolving Definition of Subwatershed Planning

The term "Sub-Watershed Planning" refers to an approach to water resource and land use management that conforms to the boundaries of a subwatershed, and that respects the requirements of the ecosystem within the subwatershed as a fundamental part of the planning process.

This approach reflects an awareness of some of the limitations of previous approaches. Traditional planning for developing areas was based on parcels of land defined by political or development area boundaries. Such an approach neglects the physical reality that stormwater flows according to topography, which only coincidently corresponds to the definitions of land ownership or government. It also tended to result in a piecemeal approach to drainage planning. Opportunities to plan and manage interactions between properties, or to provide control measures that integrate large areas, tend to be lost as a result. Master Drainage Planning was devised as a response to this, by planning drainage on logical watershed or at least physically reasonable units. Even this advance proved to be limited, however, as increasing interest in ecological issues required that drainage and drainage corridors be resolved in a way which has minimum environmental impact. Subwatershed planning takes the problem further, by taking a broader view that incorporates environmental issues.

There is now a stronger focus on protection and enhancement of the environment, which includes protection of the form and function of the natural environment. This supplements the various water quality indicators that have been used in the past (and still are) with such interests as channel form, habitat, stream cover, and so on. As well, participation in the planning process by the public and by other stakeholders tends to be stronger.

These factors have tended to add to, rather than replace, the general principles of Master Drainage Planning. A consequence of this added range of interest, is an expanded range of required technology. Subwatershed planning tends to be marked by studies and investigations that not only address drainage requirements, but include studies of species, aquatic habitat, terrestrial habitat, and ground water.

The Sub-Watershed Planning process is not yet fully developed. Ecological models are imperfect. The understanding of control measures is still developing. The ability of municipalities and the Province of Ontario to fund the significant capital and operational costs of stormwater and other service facilities is limited, and costs are escalating. Therefore, even though the present state of the art is an effective and useful process, and a substantial improvement on past practice, the process will no doubt continue to evolve.

The Context

The role of the Sub-Watershed Plan is best understood by considering as it relates to two other major elements in watershed planning, namely the **Watershed Management Plan**, and the **Stormwater Management Plan.** To ensure effective stormwater management, all three components of watershed planning must be completed and be directly related to the municipal planning process.

- **Watershed Management Plans** are comprehensive strategies, developed on a watershed basis, that establish goals and approaches to water management on a broad level. The plan documents the major physical, chemical and biological characteristics of the watershed, and establishes existing and potential water uses. General management methods are evaluated and, and management approaches are selected on a watershed basis.

  Watershed Management strategies are linked to municipal Official Plans which set out the objectives and policies that are used to guide development. The Official Plans should contain the stormwater management goals and targets established in the Watershed Management Plan.

- **Sub-Watershed Management Plans** address the requirements for stormwater management on a finer scale of detail. It develops a plan consistent with the Watershed Plan, and further defines stormwater controls in more detail and with a greater representation of specific measures.

  This planning level is at the same physical scale as the municipal Secondary Plan (which provides a basis for planning details such as land use and transportation corridors). Developing these two plans simultaneously will promote the optimization of all resources within the sub-watershed.

- **Stormwater Management Plans** are the next level of detailed planning. Stormwater Management should be considered at an early stage in the subdivision design process because it may significantly affect such items as the layout of the lots of the subdivision.

  The Stormwater Management plan is the device that sets out measures that will assure the effective implementation of stormwater management facilities when the actual design of subdivision layouts and associated management measures is completed. At the same time, it is at a level of detail such that it can remain responsive to and compatible with the other service needs of a development. Therefore, the Stormwater Management Plan and the Plan of Subdivision should ideally be developed together or in close coordination.

Thus, the Sub-Watershed Plan provides the link between the services-oriented Stormwater Management Plan, and the goals-oriented Watershed Plan. It pays close attention to ecological function, and balances that function with other servicing objectives including flood protection.

The Benefits

The desirability of Sub-Watershed planning can be considered in more concrete terms than a simple recognition of environmental sensitivity. There are a variety of factors that promote the concept as a valid and distinct part of the planning process.

A Balanced Approach By considering ecological issues according to each watershed, objectives related to habitat and other environmental considerations are developed in terms that are meaningful in the local context. The roles and requirements of the various 'soft' management elements of the system are better understood, and significant issues can be differentiated from less important considerations. Trade-offs among development issues and environmental consequences can be better managed to achieve an effective conclusion.

Communication and consensus. The systematic process involves participation and review by numerous regulatory agencies. Their agency objectives and requirements are thereby incorporated into the Plan. This facilitates the approval process and can reduce the occurrence of inconsistent reviews, lengthy delays, multiple submissions and other consequences of late submission of development plans to the regulatory community. As significant is the public involvement. Early and appropriate public interaction is a material benefit of the process, since values and objectives are better defined, and a consensus easily achieved and accepted.

A comprehensive scope. By assembling and reconciling diverse physical issues in a single document, the chances of encountering problems in subsequent plans and designs are reduced. The developer should not need to deal with conflicting objectives, regulations, or prior plans. These types of problems will have been encountered and reconciled during the generation of the subwatershed plan.

Savings. Time is money, and a process which is streamlined has an inherent benefit. As well, however, a clear understanding of true environmental values, and appropriate objectives, supports the expenditure of funds for environmental protection in the most effective way.

Long term sustainability. Subwatershed planning promotes a sustainable environment, and therefore also promotes the long-term sustainability of the natural system. Such things as channel stability, system operation, and long term performance of quality control devices, are all enhanced by the subwatershed planning process. This inherently improves the long term prospects of the service system as well as the natural environment.

Recognition of these factors is substantial, and increasing. The Environmental Assessment Advisory Committee has supported integrated environmental and land use planning in a number of its reports on local planning and approvals. Specifically, the committee suggests identifying the long-term costs of traditional development practices (including subsequent remediation costs) to compare with the costs of conducting preventive, subwatershed planning and implementation.

In summary, it is clear that, in concert with other plans and programs in Ontario, Subwatershed

Plans can support the development of a positive regional, economic and social environment in the Province of Ontario. By resolving and streamlining numerous planning requirements, a sound Subwatershed Plan can encourage new development. In turn, that new development will be linked with a healthy and viable natural environment, protected and preserved as an integral part of the development plan, and responsive to the public interest. Taken together, these benefits promote the growth, health and economic stability of the community.

3.2 GOALS AND OBJECTIVES OF THE SUB-WATERSHED PLAN

The benefits and considerations of Sub-Watershed Planning must be stated in terms of clear and specific goals and objectives if they are to be realised in a dependable way. These goals and objectives will be partly a function of the local situation, since the existing Watershed Plan (if any), the developing Official Plan, the physical environment, and the public interest will all play a part in their development. Even so, some aspects will be common to all Sub-Watershed Plans. They must, over the entire subwatershed area:

- **Provide a vehicle for public participation in the planning process.** Public information programs, and methods of responding to public input must be incorporated.

- **Identify and document the areal distribution, status, significance and sensitivity of natural communities.** Major environmental features of the area and their linkages must be addressed, and the factors which govern their sustainability identified. The environmental features considered should include the quantity and quality of surface and ground water, aquatic and terrestrial habitat, fisheries and wildlife communities, and habitat, etc.

- **Identify and reconcile regulatory requirements.** Appropriate agencies must be identified and involved in the planning process at an early stage, and involved in identifying key regulatory interests, if any, in the particular area.

- **Establish management goals and objectives.** Where a Watershed Plan exists, it will provide watershed goals and objectives that must be focused in subwatershed plans. A vision of the area, sensitive to intended uses and to the sound principles of environmental management must be established and translated into concrete goals and objectives. Such factors as recreational use, water supply, ecosystem support, and stormwater conveyance are considerations in the identification of use.

- **Identify constraints imposed by environmental sensitivity, flood hazard or other physical limitations or features.** Those areas and features which are directly sensitive (such as important habitats) or indirectly sensitive (such as buffer lands or recharge areas) must be identified and defended. Areas constrained from development, and features constraining development, must be identified. Sensitivity must be interpreted not only in terms of Provincial legislation, but in terms of the watershed goals and objectives.

- **Identify lands which are not constrained.** Those lands which do not demonstrate environmental constraints are, from an environmental point of view, developable. Servicing plans will affect this conclusion, but development can occur within

unconstrained lands provided that such development is appropriately guided (stormwater controls etc. are still necessary).

- **Assess the short and long term potential for development which may adversely affect the environment.** This will require an evaluation of the consequences of development in those areas not constrained by environmental features. This will establish what mitigation measures will have to accompany development, and may result in identification of added constraints to development.

- **Identify and specify the most effective Best Management Practices (BMPs) for the area.** Based on need, as established in the Watershed Planning process, BMPs types and functional criteria must be selected. This must be expressed with care. At later stages of planning and design information not available during the Sub-Watershed Planning process generally becomes available, and some fine-tuning of the Plan is often appropriate. It is important to avoid over-constraining the area, and run the risk of inadvertently preventing appropriate variations on the theme established by the Sub-Watershed Plan. Therefore, BMPs must at this stage be formulated in terms of intent and performance as much as possible. At the same time, benchmark and basis for comprehensive planning, substantial detail on the location, function, and the sizing of BMPs envisaged in the Sub-Watershed Plan must be provided.

- **Provide an implementation plan.** This must address factors which might affect the sequence of implementation during partial development stages, and must identify control measures which may be particularly critical during implementation.

- **Outline requirements for monitoring programs.** This may include monitoring plans to verify performance or continued sustainability of the critical environmental features or protective measures.

- **Provide technical information** that will assist in the development of Community Plans and the design of subdivisions.

- **Provide effective communication of the Plan and its basis.** The Plan must be communicated fully, including assumptions, methods, and limitations. There may be significant technical detail in such a plan, yet it will have a wide target audience, including general public and scientific participants. For this reason, the need for rigour must be tempered by the need for wide communication. There is often a need to provide simplified summary information which interprets the technical program for a less technical readership.

3.3 THE LINK WITH OTHER PLANNING PROCESSES

General Considerations

At present, there are a number of planning mechanisms in place in Ontario. The process does function, but does not presently proceed in a way which is integrated in a comprehensive way. The Sub-Watershed Plan is comprehensive within its own domain but, as described above, is not fully or necessarily integrated with the Official Plan development or with other planning activity.

Since the same physical systems are approached and addressed by these various planning activities, the potential for circular interaction is real. A land use planning decision can affect a variety of watershed planning issues; the converse is also true. Therefore, if the land use and watershed planning issues are not concurrent, or linked, they may be incoherent. To avoid this, the Sub-Watershed Plan is often required to undertake some sort of evaluation of land use planning issues in order to complete its direct objectives. Assumptions on demographic change or population growth patterns are basic to the Sub-Watershed Plan. If not already available, these issues must be either fully completed or at least functionally addressed as a part of the Sub-Watershed Plan.

In any particular location, a review of the state of the various possible planning activities is a necessary first step in Sub-Watershed Plan development. This is the only way to determine what information is available, what is being developed, and what will be required on an acceptable interim basis in order for the Sub-Watershed Plan to proceed.

It is noted that variability between locations can be substantial, so no completely general rule can be formulated. Municipalities have the legislative authority and political responsibility to undertake comprehensive land use planning which considers environmental issues. Generally, the result is that Sub-Watershed plans will not be the major or only determinant of land use. They most likely will affect the determination of lands not constrained by environmental issues, and may affect the density of development. The actual development forms and land uses will be strongly affected by other factors, including transportation, service and other requirements.

An attempt should be made to integrate activity, if only on an information exchange basis. The existence of Sub-Watershed Plan evaluations of natural features and opportunities should be communicated to the affected municipalities. In return, developers of the Sub-Watershed Plan should seek out other planning, analysis or design activity which has defined service routes, corridors or other relevant plans. Ideally, servicing studies should lag behind the Sub-Watershed Plan elements that identify environmental constraints and opportunities.

The Environmental Assessment Process

Particular attention must be paid to the concurrent requirements of Environmental Assessment (EA) Act. As the Subwatershed Plan deals with substantive environmental issues and may incorporate major facilities, it may require implementation of facilities or practices falling under the EA Act. In that event, the Plan must meet the requirements of the EA Act before any other provincial or municipal approvals for the project may be issued. This possibility must be considered at the time the Sub-Watershed Plan is formulated.

Fortunately, it is commonly recognised that the process required by the EA Act is not incompatible with many of the principles of the Sub-Watershed Planning process. If specifically targeted during development of the Plan, it may be that the EA Act requirements can be substantially met or supported by the Planning process.

A review of the state intent of the EA Act makes it clear why this is so as a general principle. The EA Act was established "to provide for the protection, conservation and wise management of the environment through planning and informed decision making." Successful planning under

the EA Act consists of five key features: consultation with all affected parties; consideration of a reasonable range of "alternatives to" the undertaking and "alternative methods" of implementing it; consideration of all aspects of the environment; systematic evaluation of the net environmental effects of each alternative considered; and provision of clear, complete documentation. Although the two processes are not complete substitutes for each other, they are in a broad sense complementary.

EA requirements as they relate to Sub-Watershed Plans will vary depending on the proponent and the type of project(s). Depending on scale and nature, some projects resulting from the Sub-Watershed Planning process may be exempt from the EA process. In some cases, a particular project may require an individual Environmental Assessment, which can be a major undertaking. Alternatively, the Class Environmental Assessment (Class EA) process may provide a basis for approval. In fact, experience suggests that the majority of projects resulting from Sub-Watershed Plans will fall under this category (for example, see "Class EA for Municipal Sewage and Water Projects" (Municipal Engineers Association, 1993; or, "Class EA for Water Management Structures", The Association of Conservation Authorities of Ontario (ACAO), 1992).

The EA process in any form can be a substantial activity. Consideration should be given to this issue at an early stage in the development of the Plan. Given the potential complexity of the EA process, special advice on this issue should be sought.

3.4 THE TECHNICAL ELEMENTS OF SUB-WATERSHED PLANNING

3.4.1 An Overview of the Process

Experience suggests that an effective way to proceed with development of the Sub-Watershed Plan is to stage the work. This allows the planner to attempt to effectively integrate technical components of the Sub-Watershed Plan study, with other information gathering and planning activities.

For example, seeking to gather all data which might be required for all purposes is a useful ideal, as it implies that information gathering can be coordinated to reduce cost and improve results. The risk is that the time frame for development of the Sub-Watershed Plan may be hindered. However, this must be weighed against the benefits of being able to make decisions with a full awareness of related watershed issues.

It is suggested that, in general, two phases be identified. Many breakdowns of the effort of Sub-Watershed Plan development could be devised. This is not key; it is the attention to a logical sequence that is important. As envisaged here, the first of two phases is oriented towards identification of needs, and the second towards development of a plan. A major point should be made here. A hallmark of instances where an accepted Sub-Watershed Plan is difficult to achieve is that there is inadequate attention to 'Phase I' activity. Poor information, and particularly a poor vision of the objectives for the watershed, will lead to a study that proceeds smoothly up to the point where it is near completion but collapses at that point. The unsound basis for the Sub-Watershed Plan becomes evident under public and regulatory scrutiny.

Phase 1 essentially gathers together all factors that will enable analysis to proceed, but undertakes relatively little direct analysis. The complexity of Phase 1 work depends on whether watershed plans or other relevant environmental planning studies have been completed. In particular, a valid Watershed Plan will provide substantial information and definition to support the Sub-Watershed Plan. Without this, the essential aspects of a Watershed plan may have to be developed in order to complete the Sub-Watershed Plan. Either way, Phase 1 should:

- gather all data, if necessary identifying required monitoring
- establish goals and objectives for the Sub-Watershed
- identify environmental constraints
- identify major opportunities for management and control
- establish review requirements for the development of the Plan

Phase 2 is the activity which actively develops and tests a Sub-Watershed Plan. It identifies the final product, including:

- areas to be protected
- characteristics of development areas
- management practices for open space areas
- BMP programs to mitigate impacts of development
- an implementation strategy

Typically, the process is carried out by a consulting team with specialised skills in the area of Sub-Watershed Plan development. Academic support for special areas of investigation is common. A Steering Committee, representing the joint interests of regulatory, municipal and sometimes public representatives will normally be struck, to provide a basis for regular review and approval of the conduct of the study leading to the Sub-Watershed Plan.

3.4.2 Defining the Sub-Watershed Boundaries

Although it is possible to accurately define drainage basins of various sizes according to topography, there is no standard way of establishing subwatershed boundaries as they relate to planning. Physically, a watershed and sub-watershed are distinguished more by a choice of scale than by any truly defendable scientific definition. Any drainage basin could be viewed as a watershed at some scale. Realisticly, Watershed plans tend to be at a scale that encompasses several municipalities, or areas of that extent, while Sub-watersheds tend to encompass one or more sub-divisions. There are a variety of factors leading to a definition of the Sub-Watershed area:

- the location and extent of proposed development activities

- the existence and nature of sensitive downstream water-related natural features, uses, conditions or hazards

- available watershed plans specifying subwatersheds for study

- an agreement on boundaries with regulators

Once the general scale of the problem is established, the physics of the problem provides a more precise definition. The most downstream point in the receiving water tends to define the total sub-watershed area. Even there, the definition of the study area may require care, as a consequence of developing technology. The hydrogeologic system is now a common interest in Sub-Watershed Planning. The boundaries of that system may not follow the precise alignment of the limits of the hydrologic system. Therefore, the physical limits of the sub-watershed planning area may extend beyond the topographically defined basin area.

3.4.3 Information Gathering

The techniques in analysis, and the particular site topography, will affect information requirements to some degree. For example, mapping contour intervals will be different in areas of high relief than in areas which are flat. Therefore, development of the Sub-Watershed Plan requires that the steps and methods in analysis be identified. At the outset, a general principle should be followed. If information may change a decision, it is required. If it will not, reconsider its necessity. Information for its own sake is not a valid undertaking, but experience shows that it is a common result. Response to public interest, lack of forethought (especially in terms of model requirements), measurements taken 'just in case', and other factors are all common contributors to this. Since information gathering is also an expensive undertaking, this should be discouraged.

- Drainage systems and patterns
- Geomorphology
- Geology and soils
- Aggregate resources
- Hydrogeology
- Water quality trends
- Agricultural practices
- Fish and wildlife
- Storm water management facilities
- Flooding trends
- Infrastructure and services
- Housing needs
- Erosion sites
- Waste disposal sites (active, proposed, closed)
- Existing and proposed land use
- Planning designations
- Recreational uses
- Transportation corridors
- Water use/taking/conservation
- Discharge/recharge areas
- Precipitation/climate patterns
- Baseflow/flow records
- Riparian vegetation/woodlots
- Wetlands
- Hazard lands
- Pollution sources (point, non-point)
- Channel alterations
- Environmentally Significant Areas/ Areas of Scientific and Natural Interest

A comprehensive base map, at a 'manageable' scale, is a highly useful device. Comprehension is very much facilitated if a 'birds eye' view of the area can be presented. Numerous detailed maps may supplement this overview. At the same time, the profuse detail in the development of a Sub-Watershed Plan makes it difficult to have everything on one figure. A logical grouping of information assists in separation of data into related groups, as shown in table 3.2. A caution is made, however, that this will not lead to solving the problem in a segregated way. The essence of the Sub-Watershed Plan is its ability to inter-relate the various aspects of the plan. It is noted that GIS can be a powerful tool in this area, since the flexible rendering and contrasting of information is a strength of that technology.

TABLE 3-2. Suggestions for Overview Mapping in a Subwatershed Plan.

RESOURCE FEATURES	DETAILS TO BE MAPPED	SOURCES OF INFORMATION
Aquatic Resources	• Surface water sampling stations • Fish and invertebrate collection stations • Display all main stem and tributary drainage features including intermittent or ephemeral streams • Map riparian zones based upon aerial photography • Identify springs, kettle lakes and recharge areas	Primary • MOEE/MNR/CA (MNR district fish management plans) water quality studies or fisheries inventories • Aerial photographs • Field visits Supplementary • Scientific literatures • Local anglers/naturalists
Soils and Geology	• Soil types/classifications • Indicate drainage characteristics (e.g., well drained, moderately drained, poorly drained) using hydrologic soil groups	Primary • OMAF reports and maps • MOEE well records • Conservation authority • Ontario Geological Surveys • MNR - District plans • Engineering Consulting Reports
Erosion Sites	• Depict the location of any known erosion hazards to structures and life as well as the instream environment • Indicate the type of erosion, locations, extent, and course(s)	Primary • Conservation authority inventories and work programs • Aerial photos • Walking surveys will be required in almost all cases to confirm earlier inventories, unless inventory is very recent
Forest Resources/ Woodlots	• Boundaries of woodlots, hedgerows • Show extent of forest cover in riparian areas • Composition (main tree species) • Ownership (public or private) • Representatives, i.e., unique, common, high quality for county/townships, etc.	Primary • MNR forest resource inventory mapping • MNR/CA designations of ESAs and ANSIs • Aerial photographs • Boundaries on OBM 1:10,000 mapping Supplementary • Field checks • Naturalist groups • Scientific literature

3.4.4 Establishing Constraints and Opportunities

The environmental sensitivities defined for the area constitute constraints, either directly or indirectly. For example, wetlands themselves are sensitive and constitute direct constraints. The necessary buffer space around those lands constitute indirect constraints. Other constraints include existing development patterns, transportation corridors, or utilities that might impede or influence development patterns.

Opportunities include locations where drainage patterns favour efficient location of BMPs, where mitigation of existing damage would be a simple and effective part of the Sub-Watershed Plan, or where other factors that would be a positive part of the Sub-Watershed Plan can be identified.

Key features that are often associated with constraints or opportunities include:

- aquatic and terrestrial ecosystems and habitats
- wetlands
- watercourses, including channels, floodplains and valleys
- fisheries and wildlife
- topography and soils
- natural and cultural heritage systems

Substantial review of these constraints and opportunities is important, since they will be fundamental to the Sub-Watershed Plan.

3.4.5 Analyses

Technical analyses are carried out to provide assessments of factors that cannot be directly measured. This includes projections of hydrologic and other impacts of future development, BMP performance and so on. In essence, technical assessments perform two functions. They provide estimates of information which cannot be measured (through cost or because it does not yet exist), and they support solution identification (seeking of optima, GIS presentations, financial calculations etc.). Other modules in this series examine the technologies involved in some of these assessments, and are not dealt with in detail here.

In general, it is important to recognise the multi-disciplinary expertise that is required from various branches of the scientific and engineering community in the development of the Sub-Watershed Plan. Present approaches require hydraulic and hydrologic analysis, groundwater analysis, biology, engineering, planning, financial, legal, and public relations skills as a normal minimum. A developing trend is to recognise that a key to the process is a professional skilled in the interpretation and integration of these various and diverse disciplines.

Rapid evolution of the technology is evident in a number of necessary technical areas. Even recent studies tended to concentrate on hydrologic approaches based on single event surface runoff models. Current approaches require continuous simulation and increasingly require a substantial assessment of groundwater response. Snow melt effects can be an important part of the study, where previously the problem was focused on summer event conditions. Other examples can be cited. The key is to recognise that successful development of the Sub-Watershed Plan rests on successful response to developments in technology.

3.4.6 Identification and Selection of Management Options

The analysis of potential impacts of development, and the interpretation of those impacts in terms of environmental constraints, defines the need for management. The opportunities for various management options (limited by the physical system), define the possible range solutions.

For example, one may consider results of post-development flood analyses. Flood-susceptible structures represent a constraint, and increases in surface runoff would require management. Options for management of the problem might include hydraulic improvement, peak flow control, or other measures. This information can be used to establish the level of quantity control which must be provided to accommodate development.

Analysis of the ecosystem may identify certain valleys as sensitive habitats which become constraints. Changes in flood characteristics would likely require management. Volume attenuation, peak attenuation, or habitat replacement may be management options.

Other ecosystem assessments might identify certain wetlands as sensitive to changes in the groundwater water table, and therefore constraints to development. Management options might include recharge maintenance in the development area, re-location and rehabilitation of the wetlands, or enhanced recharge near the wetlands.

Development of the alternative options in consistent sets of alternatives is the process of solution

generation. Choosing the 'best' solution, which is likely to be a compromise, is the challenge.

Alternative plans should be evaluated on the basis of criteria developed for the subwatershed. Evaluation criteria will include such factors as:

- responsiveness to watershed goals and objectives,
- cost-effectiveness,
- ease of implementation,
- maintenance needs,
- safety,
- aesthetics,

and so on. Alternatives should be presented to the Steering Committee, if it exists, and to the public at this stage, at length.

Once the process of review and selection has been completed, the basis of all the information and comments gathered, a preferred subwatershed plan is drafted. The plan includes mapping of areas of preferred land uses and those for which certain practices or structures are proposed. The final step in plan development is review and adoption by all agencies and the public.

3.5 THE PROCEDURAL ELEMENTS OF SUBWATERSHED PLAN DEVELOPMENT AND IMPLEMENTATION

This section describes the steps which should be followed in organizing and managing the development of a Sub-Watershed Plan. This framework is intended to assist coordinating agencies, and especially the project coordinator. It provides information on why and how these studies are started, what issues are to be addressed, and the timing of various activities.

Sub-Watershed Plan development can be divided into three stages:

- Setting the Stage
- Aligning the Interests
- Preparing the Plan
- Adopting the Plan

3.5.1 Setting the Stage

In the more rapidly urbanizing watersheds of southern Ontario, staff of conservation authorities and municipalities commonly face pressures to provide answers to agencies, supplying information and fulfilling study requirements, and to provide input into the review and approval of development plans. In these areas, development pressures can generate concerns for the protection and management of the natural environment. Generally, local governments largely welcome and promote land development and they see the subwatershed/watershed planning process as an effective way of accommodating the apparently conflicting demands of environmental protection and urban development/land uses in an expedient manner.

Either a watershed plan, if there is one, or an Official Plan may endorse and/or recommend the

development of a Sub-Watershed Plan. In the latter case, the Official Plan should clearly identify the need for subwatershed plans to be developed in support of proposals for land use change.

At this stage, a number of actions can be taken to establish the framework for developing the Sub-Watershed Plan.

- **Establish and secure agreement among stakeholders on the need** for a Sub-Watershed Plan. Obtain commitments from parties and agencies for participation, support, adoption and implementation of the plan.

- **Identify the apparent main issues or concerns** in the subwatershed. Although key issues may not always be immediately apparent, the general character of the subwatershed area will be known in most cases. An overview report may be helpful in focusing this information. It may include the presence, features and status of:

  - watercourses and valleys (channels, buffers)
  - downstream flooding and/or erosion problems/hazards
  - water quality
  - fisheries potential (cold or warm water)
  - wetlands
  - Environmentally Significant Areas or Areas of Natural or Scientific Interest
  - woodlots
  - recreation opportunities
  - agricultural land uses
  - land development proposals
  - water-takings, water uses, water conservation
  - ground water recharge/discharge areas, baseflows
  - municipal servicing needs

  This ability to document the main features of the watershed is useful during the early discussions of the Sub-Watershed Plan. One should not be concerned, at this point, with overlooking issues or concerns in the study area which may prove important at a later stage. These issues will be more firmly established during subsequent stages of plan development.

- **If possible, establish an appropriate coordinating agency.** The local conservation authority is generally the agency most suitable for coordinating the preparation of a Sub-Watershed Plan, particularly where the subwatershed crosses municipal boundaries. An upper tier (regional) municipality or, in the case of a small subwatershed, totally contained within its boundaries, a local municipality may undertake coordination. In municipally unorganized areas, and in areas outside of conservation authority jurisdiction, MNR and MOEE may take a lead role.

- **Determine funding responsibilities.** All parties should establish the extent of funding that will likely be required, the extent to which each party could contribute, and possibilities for phasing the undertaking. The phasing of subwatershed plan development may allow for cooperative sharing of costs among government agencies and the

development community by spreading fiscal demands more comfortably over time. It also allows for prioritizing issues needing attention, and thus, for better estimation of costs.

3.5.2 Aligning the Interests

Once the basic information that defines the early understanding of the problem has be generated (i.e. the stage has been set), there should be a careful attempt to identify the individuals and interests that must be involved or addressed during the course of the study. A major part of this process is in the striking of a Steering Committee, with the mandate to review study progress and advise on policy issues that affect the technical conduct of the Sub-Watershed Plan. During this process, and after the identification of a Steering Committee, the Terms of Reference for the study must be firmed up. As well, a team to conduct the technical activity must be identified. Following are some key actions:

- **Select a qualified Project Coordinator.** This individual is the focal person, relating the Steering Committee, agencies, and consultant to each other and to other parties to the process. Selection of this person is a key factor for ensuring the success of the subwatershed planning process. Critical strengths of the position are:

    - **A basic understanding of the issues.**

    - **Multi-agency perspective.** Each agency's mandate and issues of concern should be understood.

    - **Effective leadership and communication** skills are needed for the coordinating role of linking technical experts, planners, stakeholders and the public.

    - **Ability to anticipate and resolve conflicts.**

    - **Project management** skills to ensure that budgets and schedules are maintained.

    - **Agency support**, i.e., time and resources to do the job.

    - **Ability to facilitate timely input** from the public and non-government organizations.

- **Establish a Steering Committee.**

    A steering committee should be defined to provide review and policy guidance, during the course of the study, to guide the Project Coordinator. Steering Committee members should:

    - effectively represent their organization
    - have the authority to commit to the plan
    - be willing to negotiate to resolve conflicts
    - commit time and effort where required to meet deadlines

This last point is key. An unfortunate event is the periodic change in composition of steering committee members. Continuity, particularly in the critical review agencies, is a highly important contributor to effectiveness. Section 3.6 addresses Steering Committee function in more detail.

- **Confirm physical limits.** The project coordinator, in consultation with the Steering Committee, should confirm or redefine previously identified boundaries of the subwatershed.

- **Complete/Expand the Data Base Overview.** A key step in beginning the plan development process is a review of existing data. The project coordinator should expand the initial subwatershed overview with relevant resource information from other involved agencies. This does not have to be an exhaustive inventory of data, but rather an assembly of some of the most relevant information. Examples, with sources, of this information are:

Ministry of Environment and Energy - air, surface and ground water quality, existing and proposed landfill sites, past/present studies, sewage treatment plants best management practices

Ministry of Natural Resources - floodplain management fisheries, wildlife, wetlands, Areas of Natural and Scientific Interest (ANSIs), provincial parks, Crown lands, forest and aggregate resources, unstable slopes, geological maps

Local Municipality - proposed development plans showing limits of development; regional and local environmental, ground water studies, existing environmental provisions, transportation and servicing infrastructure

Regional Municipality - regional/county knowledge of ground water, transportation, infrastructure, Environmentally Sensitive Areas (ESAs)

Ministry of Transportation (Ontario) - provincial roads, existing and proposed drainage systems

Management Board Secretariat - government lands, proposed land uses

Ministry of Northern Development and Mines - mines, mine tailings ponds, development areas, geological maps

Ministry of Culture, Tourism and Recreation - natural/cultural heritage areas

Ministry of Housing (Regional Housing Programs Offices) - housing policy statements and objectives for local areas

Ministry of Agriculture and Food - significant farm lands, municipal drains, land stewardship projects, soils reports, agricultural land use mapping

Conservation Authority - Environmentally Significant Area designations, erosion site inventories, flood and fill line designations, shoreline management, existing master drainage plans, watershed plans, conservation areas

Universities and Community Colleges - special studies, technical expertise, research or masters thesis

Special Interest Groups - specific reports or inventories, e.g., Federation of Ontario Naturalists, Ontario Federation of Anglers and Hunters, Ducks Unlimited, Trout Unlimited, Conservation Council of Ontario

- **Tour of Subwatershed.** Tours can provide field verification of the existing knowledge base, clarification of various issues, and identification of areas of special concern.

- **Develop Preliminary Goal Statements.** Through the perspective gained by touring the subwatershed, and knowledge of the key resource features, the project coordinator should develop a set of statements for the subwatershed. Goal statements should be simple and measurable. It should be understood that as public input and other information arrives, during the early stages of the study, the major goals should be reviewed and ratified.

- **Terms of Reference.** The Terms of Reference will clearly identify the goals and objectives, the work program, the project schedule and the expected product. Terms of References for watershed/ subwatershed studies have been prepared for a number of projects in southern Ontario (generic Terms of Reference e.g. Region of Waterloo).

- **Steering Committee Study Startup Meeting.** At this point, there will already be identified a draft study area boundary on established knowledge base, key subwatershed issues, a preliminary set of goal and objective statements for the study area, study budget needs, and draft Terms of Reference. The Steering Committee must reach agreement on each of these items at this stage, prior to presentation to other interest groups and the public.

- **Start Public Involvement.** The project coordinator and Steering Committee members should determine key public interest groups in the subwatershed, including ratepayers groups, naturalists clubs, sporting groups and others. The early, effective, and continued involvement of public is one of the most important tools for achieving the support needed to develop and implement the plan. The project coordinator should carefully consider how and when the public should be involved in this process.

- **Identify Funding Alternatives and Budget Needs.** Funding support for development of the plan should already be established by this point. The project coordinator should define the specific budget needs, identify potential partners, and negotiations should begin to secure project funding for implementing the plan.

- **Select Project Consultant.** *Requests for Proposal* are sent out to qualified environmental engineering firms and scientific and planning firms of specialized expertise relevant to the study goals and objectives. These proposals are received and reviewed by the

Steering Committee according to an evaluation procedure usually adopted by the Steering Committee. A consultant or consortium of consultants is then selected to undertake the study.

3.5.3 Preparing the Plan

The steps in section 3.4 in fact outline the basic requirements of the technical activity that leads to a plan. Briefly, these are:

- **Define Data Requirements and Collection.**

  Recognising that not all studies have to be "cadillac," big-dollar studies, and tying the information gathering into the analyses required for the study, the data requirements of the study should be addressed. The information needed to conduct the study and to develop planning methodologies will be established in consultation with the consultant, public and agencies under the guidance of the Steering Committee.

- **Prepare the Plan.**

  The available data is used to develop a number of strategies from which a preferred alternative is selected and recommended for adoption as the SWM Plan. The various agencies and the Steering Committee provide review and guidance throughout this process.

3.5.4 Adopting the Plan

When all stakeholders agree on a Sub-Watershed Plan, the coordinating agency works with participating agencies to coordinate implementation of the plan. As noted, in section 3.4, the questions of affordability, cost/benefit and potential negative consequences of the measures proposed in a subwatershed plan will have been reviewed and agreed to by this point.

Adopting the plan, as experience shows, must be more than accepting and approving the Sub-Watershed Plan document. Aggressive commitment, by the key municipality or agency, is the factor that will make the Sub-Watershed Plan a reality, or relegate it to the realm of 'another study'.

In large measure, the ease with which the plan is adopted will depend on the effectiveness of the preceding stages in the process of developing it. The responsibilities for implementation and the provision of operating costs now fall to participating agencies.

3.6 THE STEERING COMMITTEE

Composition

For best results, as demonstrated in previous watershed planning efforts, the Steering Committee should be small, say, 6 to 12 people, and should consist of representatives from the core agencies, including both lower and upper tiers of affected municipalities, the local conservation authority, and the Ministry of Natural Resources and the Ministry of Environment and Energy. Other agencies, developers and/or members of public interest groups may also be appropriate participants on the Steering Committee, and, on the basis of their mandates, may become involved at certain decision points.

Municipal planning and public works departments should both be represented by senior level staff; representatives of departments such as parks, recreation, engineering and environment could also play a part as appropriate.

Consistent participation by knowledgeable Steering Committee members is a vital part of the smooth functioning of the study.

Actions

The Steering Committee should convene at the outset of the process to discuss:

- specific concerns and interests in the subwatershed
- available and needed data base
- land use assumptions within the subwatershed for hydrologic analysis
- confirmation of subwatershed boundaries
- municipal servicing needs, expectations and priorities
- subwatershed resource management objectives, tailored to suit individual subwatershed conditions

Once the study is in process and the study team has a good understanding of the natural systems within the subwatershed, the Steering Committee should discuss significant issues with the team, as required by the team, to provide guidance on policy implications. Appropriate interaction points include reviews of:

- the assembly of existing natural features, processes and water-related linkages
- opportunities for protection, enhancement, rehabilitation and development (integration of resources management objectives and municipal needs/priorities with existing natural features, processes and linkages)
- prioritization of watershed goals
- the selection of criteria or targets
- identified opportunities and constraints
- the long list of alternative plans
- the selected alternative

Other Steering Committee activity, for example in the public participation programs, may also arise.

3.7 MONITORING PROGRAMS

A Sub-Watershed Plan cannot be considered complete until its monitoring program is established. Monitoring programs should be designed to:

- assess environmental changes in the subwatershed, possibly tracking the health of the subwatershed relative to earlier baseline information
- evaluate compliance with the plan's goals and objectives, and
- provide information which will assist custodians of the plan to implement and update it.

The monitoring program should be presented as part of the implementation plan for the Sub-Watershed Plan.

Custodians of the subwatershed plan have the responsibility for undertaking the monitoring program and ensuring that the information generated is used effectively. A multidisciplinary team will be required to establish an appropriate monitoring program for the subwatershed and to advise the plan's custodians of how to carry it out and how to interpret and apply the findings. Successful monitoring programs have used protocols for inter-agency transfer of information and results have been incorporated into updates of regulations, bylaws and maintenance schedules.

Monitoring programs must be practical and cost-effective to be funded in the first place or to accommodate budget constraints over the life of the plan. Monitoring programs must also be simple and verifiable, so they are little affected by staff changes.

Effective monitoring programs do not have to include extensive field studies or exhaustive laboratory scans for pollutants. Field inspections by experienced staff can be used effectively to identify whether or not the plan is working, e.g., stream banks are stable and well vegetated, trout are being caught, the beach downstream of the subwatershed remains open. An added advantage is that these staff surveys are more likely to get done, and their findings are more readily interpreted.

Monitoring programs for subwatershed plans have to consider the rate and pattern of development within the subwatershed. For example, high growth scenarios experienced in rapidly expanding urban centres will require different environmental response monitoring strategies than those for subwatersheds where the level of development is not only smaller, but spread over a much longer period of time.

3.8 PUBLIC PARTICIPATION

The purpose of public participation in any planning or decision-making process is to allow for an exchange of ideas between the planning team and the stakeholders, so that controversy can be minimized or avoided, and knowledge of stakeholder needs improved. Increasingly, provincial and municipal agencies recognize that public participation in the development of plans or projects affecting the public is a key determinant of the success of these undertakings.

Beyond communication of needs and interests, the public can be a valuable source of information. Interest groups and the public at large can provide valuable insights and

information, often bringing new ideas and a sound understanding of local conditions and aspirations. Drawing people into the planning process at an early stage can make this information available when needed.

Several key elements common to any successful public participation strategy can be identified. This participation should be managed, so that representative opinions are identified. The fact that the public represents a very large mass of individuals makes this difficult. It is important to gain access to a consensus, and strongly polar opinions may not fully reflect that requirement. As well, there must be opportunities for the larger mass of people to understand the Sub-Watershed Plan process, and communicate their interests to the study team. Both aspects must be respected, and must be seen to be taken seriously.

There are many ways to reach the public and gather their concerns and insights.

- **Printed materials**, such as brochures, flyers, fact sheets and newsletters are effective ways of informing people about the subwatershed planning process.

- **Displays** at local shopping malls, fairs, or public meetings are an excellent method of educating the public and generating "feedback" on a one-to-one basis.

- **Field trips** can be very effective in illustrating subwatershed issues to an interested public.

- **Public meetings** are important ways of generating public discussion and even debate about key watershed issues; adequate advance notice is required as well as a broad enough scope of stakeholders.

- **Public opinion polling** is a fairly successful method used in the U.S. for gathering public attitudes about water management issues.

The appropriate method will depend on the details of the study, and the level and nature of public interest. Conduct of an effective public information program is a special skill, and an important consideration in the composition of the study team.

Without public support and endorsement, many of the best-planned and engineered projects can founder in limbo, face stringent criticism and opposition, implemented poorly, or never be implemented at all. Countless examples over recent years demonstrate the importance of "buy-in" from the public. The Great Lakes Remedial Action Plan process has public involvement as an integral part of every stage of RAP development. Public Advisory Committees made up of local stakeholders participate in identifying the problems, developing feasible solutions, and assigning and accepting responsibility for actions and funding.

3.9 FUNDING

Subwatershed Plans vary widely in scope and kinds of activities required, and many jurisdictions and agencies are likely to be involved in this work. Since there is no Provincial mechanism targeted at funding this specific requirement, those participating in plan development and implementation need to be innovative in securing new and various funding sources and in properly scoping the nature, timing and extent of the work involved.

- Funding support for the many subwatershed planning initiatives completed or begun over the last two or three years has come from local and regional municipalities (directly or through conservation authority levy), developers and provincial agencies (MNR transfer payments to CAs). The relative contributions of the partners varies widely on the basis of local circumstances. A principal factor influencing private sector funding participation has been the presence of major development interests and pressure for development approvals.

- Although the mechanics of the process may be problematic, a well-designed approach to planning at the subwatershed level should allow cost savings for the development community, and in principal generate funds that can be used for subsequent studies associated with individual development proposals.

- Ongoing work that can be "re-profiled" might contribute to the needs of the subwatershed plan. For example, in areas where a significant portion of the subwatershed is already extensively developed, spending on remediation and redevelopment planning could be combined with planning efforts focusing on the developing areas. Participants are encouraged to make study costs "affordable" by a realistic scoping of study needs, phasing plan development, sharing available information and drawing on experience from other subwatersheds.

CHAPTER 4

INTEGRATING WATER MANAGEMENT OBJECTIVES INTO MUNICIPAL STRATEGIES

CHAPTER 4

4.1 INTRODUCTION

4.1.1 Training Objectives

The goal of this Chapter is to develop an understanding of:

1. the global objectives of watershed management from a historical perspective,

2. key environmental issues of importance in watershed management such as flood hazard, water quality impairment, erosion and baseflow depletion,

3. the relationship between municipal land use planning and the water resources planning process,

4. the policies addressing water resources management in the municipal land use planning process, and

5. implementation of official plan policies.

Much of the material presented in this Chapter was obtained from MOEE/MNR document entitled "Integrating Water Management Objectives into Municipal Planning Documents", June, 1993.

4.1.2 Background

This will provide an overview of the concepts associated with watershed planning and management. This module presents an approach to assist municipalities in developing official plan policies which incorporate the goals and objectives of water and related resource planning, protection and management.

Water and related resources are a matter of provincial significance because they are essential elements of our natural ecosystem. They sustain human, plant and animal life, and are important for agriculture, recreation, industry, energy production, domestic purposes, among a myriad of uses. A reliable supply of clean water is fundamental to our economic, as well as social and individual, well-being.

There is general concern, among water resource managers and the public alike about the condition of Ontario's water resources, in terms of both quality and quantity. Many municipalities are facing tough challenges in the protection of water supplies, the provision of water-based recreational opportunities, maintenance of fish habitat, flooding and erosion control,

and general maintenance of the quality and integrity of rivers, lakes, groundwater and wetlands. In these circumstances, it is important to consider the sustainability of these resources, and to manage them as effectively as possible, so that present and future generations will not need to bear the cost of necessary remediation works. Effective water management in the present will maximize opportunities for the development of economically sound communities while maintaining and improving the integrity of the ecosystem. Figure 4-1 illustrates, in a conceptual sense, the relationship between development and ecosystem management.

Land use decisions under the municipal planning process can significantly impact the quality and quantity of existing water resources. It is important that the effects of new developments and changing land uses be carefully assessed, not just on an individual basis, but taking into account the cumulative effects over time and over the wider watershed area. Land use decisions need to have regard for effective water resource planning and management to maintain and enhance water quality and quantity in the province.

The official plan in the municipal landuse planning process serves to:

i) define the municipality's goals and objectives for landuse,

ii) provide policy direction to guide land development in accordance with the Planning Act,

iii) incorporate aims and contributions of watershed and subwatershed planning, and

iv) promote and implement objectives of water and related resource planning for the entire community.

4.1.3 Provincial directions in Water Resource Management

Ontario is promoting and developing a broad watershed strategy to ensure that water and related resources are appropriately managed through the full range of planning and resource management practices that are carried out across Ontario. The need to efficiently incorporate water and related resource management into municipal official plans is addressed in the *Planning Act*. Municipalities should support and seek the fullest possible participation in the water and related resource management initiatives of other agencies in order to develop comprehensive integrated water and related resource planning programs.

Where a watershed plan has been prepared, the municipality should incorporate relevant parts of the watershed management plan into the official plan. When a watershed plan is in preparation but is not yet finalized, the municipality should state its intention to re-evaluate and if necessary, amend its official plan to incorporate new water resource management policies contained in the watershed plan.

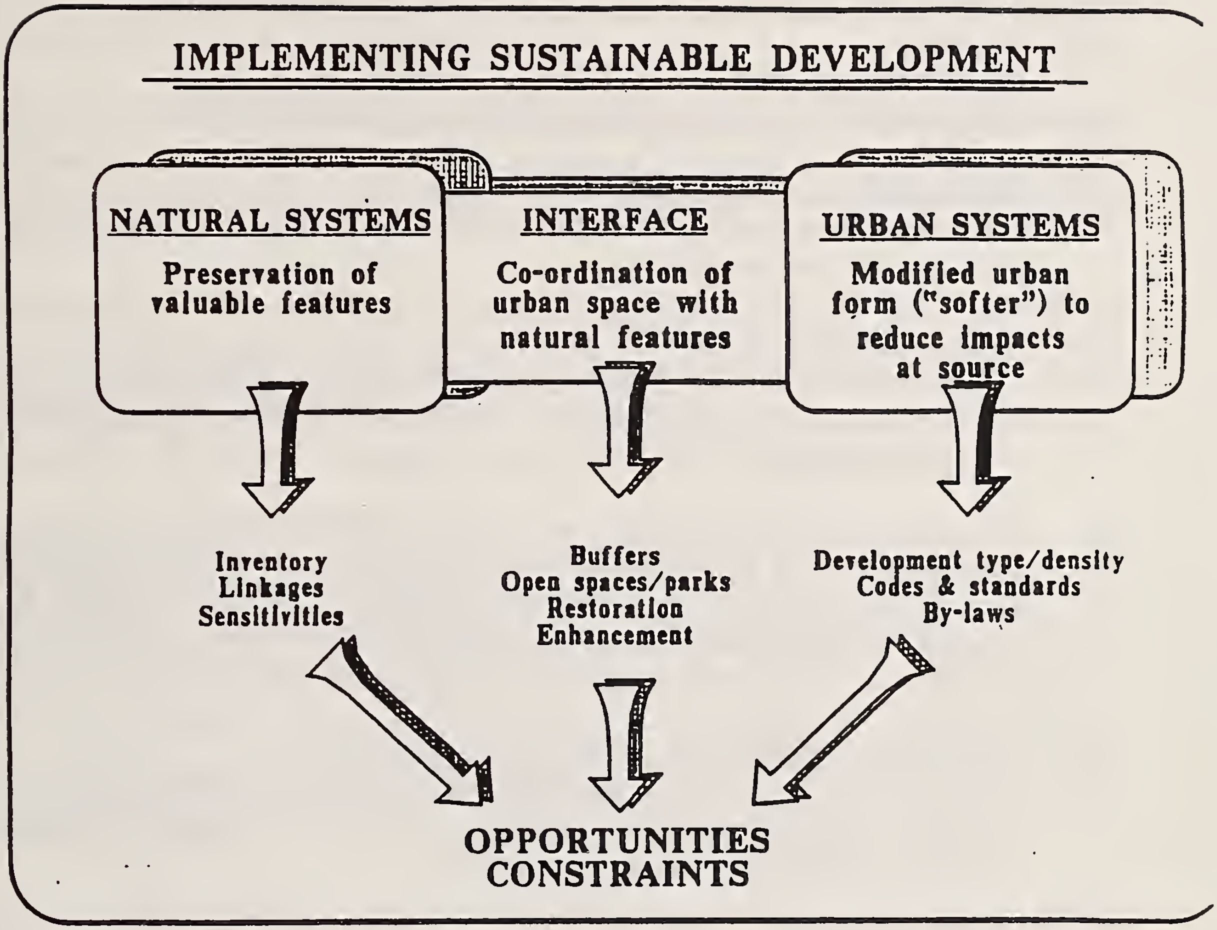

Figure 4-1 Relationship Between Development and Ecosystem Management.

In addition, municipalities should encourage and support programs to protect, clean up, and rehabilitate natural water-related ecosystems in cooperation with appropriate agencies, e.g., Remedial Action Plans, Habitat Canada, Community Fisheries Improvement Program, Community Wildlife Improvement Program. Municipalities are encouraged to consult with MNR, MOEE and local conservation authorities to identify specific water management initiatives that may have relevance to municipal planning, prior to the preparation of their official plan or major official plan amendments.

4.1.4 Overview

This module is organized into 5 sections which are summarized below:

(1) History of Watershed Planning
The historical perspective of watershed planning in Ontario is necessary to understand present trends and key issues.

(2) Major Environmental Issues
An overview of important environmental issues, such as flooding, baseflow, water quality and erosion, provides the background necessary to understand and interpret watershed management goals and objectives.

(3) Municipal Landuse Planning Versus Water Resources Planning
Since most landuse decisions are made in the context of the municipal landuse planning process, the goals of water resources planning must be recognized at this stage. Understanding the linkages between municipal and watershed wide planning, therefore, represents a fundamental element of water management.

(4) Policies and the Municipal Landuse Planning Process
Important concerns of water resources management are incorporated at the municipal planning stage through the Official Plan. A review of the specific policies, which are required to guide this process, is necessary.

(5) Implementation
Linkages between watershed and landuse planning are established within the context of the Official Plan. The Official Plan also sets out the framework for water resources planning. Implementation of the water resources planning is generally achieved by a combination of watershed plans, subwatershed plans and site management plans. The Implementation section of this module provides a brief overview of the important elements of these planning tools.

A summary discussion is also provided towards the end of this Chapter.

4.2 HISTORY OF WATERSHED PLANNING

Human activities can influence natural processes. It is apparent that the greatest proportion of water management problems and issues arise from human activities themselves. Urbanization and human activities impact our water resources. These impacts include degraded aquatic communities, loss of water supply, groundwater contamination, deteriorating water quality, and increased flooding and erosion. The population, in general, is becoming more aware of, and supportive of, the need for environmental protection and wise management, and its close relationship to the province's economic health.

Water management in this context is a complex and challenging dilemma -- to use water wisely for beneficial uses, and to maintain the integrity of the ecosystem for its intrinsic value, for all life's sake. The Royal Commission on the Future of the Toronto Waterfront expresses the same view this way:

> *"Traditionally, human activities have been managed on a piecemeal basis, treating the economy separately from social issues or the environment. But the ecosystem concept holds that these are inter-related, that decisions made in one area affect all the others. To deal effectively with the environmental problems in any ecosystem requires a holistic or 'ecosystem' approach to managing human activities."* Watershed, 1990

Runoff Quantity Control:
Traditionally, stormwater issues were primarily focused on flood hazard. Stormwater was viewed as a "nuisance"; something to be rid of, and the stream channel was thought to be merely an extension of the urban storm sewer system. Resolution of flood related problems was the primary rationale behind the creation of Conservation Authorities (CAs). During the 1950s and 1960s the CAs were involved in the construction of numerous large flood control reservoirs. The Fanshaw, Clairville, and Kelso reservoirs are legacies of this era. The role of urban stormwater in the creation or aggravation of flood hazard within flood sensitive areas, although identified in the 1930s, was not effectively recognized until the 1960s and 1970s.

Urban hydrology, a key element of stormwater management, became recognized as a distinct area of specialization during this period and the concept of stormwater management became a means of restoring the storage characteristics of an urbanized watershed back to pre-development conditions. Stormwater management (SWM) was developed for quantity control of large, flood producing, runoff events. At this stage, SWM encompassed the use of pipe storage, dry ponds, and rooftop/parking lot storage, for control of flow rate and erosion.

Runoff Quality Control:
Although its significance as a pollutant source was recognized decades earlier, concern with regard to the quality of urban stormwater runoff did not begin to emerge until the 1960s. However, it was still considered secondary to major Point Source (PS) pollution sources such as industrial effluent, combined sewer overflows (CSOs), and primary Sewage Treatment Plant (STP) discharges. It was not until the late 1970s and early 1980s, after a massive effort to cleanup these other pollutant sources failed to produce the desired water quality in the receiver, that more attention was focused on contaminants in urban stormwater runoff. During this

period facilities for water quality control were primarily detention-based controls, such as wet ponds or extended dry ponds, supplemented with street sweeping and catch basin cleaning.

Erosion Control:
The impact of urban development on stream channel morphology was identified in the late 1950s and early 1960s. However, the typical response to stream instability problems up to the 1980s, was to "improve" the channel. This involved various combinations of straightening, grade control, and hardlining of the stream. By the late 1970s and early 1980s the view of the channel as an extension of the sewer system gave way to an understanding that the stream channel and its valley system are amenities and as such, resources to be coveted and maintained or enhanced.

Baseflow Maintenance:
Baseflow represents that river or stream flow which is associated with dry weather periods. It was recognised that urbanization may impact groundwater recharge and the storage characteristics of the surface water system. Until the 1980's, when baseflow depletion became an environmental issue in response to fishery concerns, conflicts regarding baseflow were principally focused on conflicts surrounding water taking activities.

Baseflow maintenance is now addressed, in part, through constraint mapping and land use zoning which are designed to exclude or restrict development in recharge areas.

Present Philosophy:
In the late 1980s the piece meal approach to stormwater management began to be replaced with a more holistic approach based on ecosystem concepts. Under the traditional approach, development was imposed on the landscape with little regard for natural features and designed channels replaced natural drainage systems. Present approaches attempt to integrate natural resource features and land use planning to strategically locate developable areas and identify constraints and opportunities for stormwater management facilities within these areas.

As watershed plans and programs were completed and endorsed in southern Ontario in the early 1980s, the Master Drainage Plan was promoted and subsequently recognized as the preferred mechanism for the planning and design of urban drainage systems to minimize impacts of urban stormwater runoff on receiving watercourses. Although these Master Drainage Plans often recognized the importance of meeting broader environmental objectives of the watershed plans, they generally addressed only the quantity of urban runoff and its impacts and influences on flood control, erosion control and major/minor system design.

In the mid-to-late 1980s, a fundamental change occurred when the requirement to address the quality of runoff from urbanizing areas was introduced. Initially, water quality concerns focused on sediment control during construction. In addition, the importance of treating storm runoff for water quality in order to address fisheries protection and other water use issues was recognized.

Concerns for the protection and enhancement of the aquatic environment in general and fisheries resources in particular (as it relates to their value as an environmental indicator), grew to

encompass a broader range of issues to be addressed including the maintenance of baseflow, cool water temperature, and stream geomorphology. More recently, the protection of terrestrial resources and ground water systems has introduced new areas of study into these analyses and urban designs.

Figure 4-2 schematically presents the evolution of Subwatershed Plans throughout the 1980s and early 1990s. As illustrated, Subwatershed Plan issues grew from five engineering drainage related issues in the early 1980s to some 18 issues in 1990. By the late 1980s, there was the expectation that Subwatershed Plans should go beyond mitigating impacts associated with development to make recommendations for the protection and enhancement of the natural resources/features. These new objectives and approaches to Subwatershed Plans were influenced by the concepts of ecosystem planning and sustainable development that gained profile and support during this same period.

The Province of Ontario is committed to ensuring that all water resources are maintained in or enhanced to a condition that has a healthy ecosystem, adequate supply, and clean contaminant-free water. The government stated in its first Throne Speech in November 1990, *"We will act to protect our supply of clean water. We will conserve and manage this precious resource and the watersheds that support it."* Accordingly, watershed systems are managed to ensure that:

a) water resources within a watershed are available in sufficient quality and quantity to provide optimal and continuous environmental, social, and economic benefits to existing and future residents of Ontario on a sustainable basis;

b) the integrity of aquatic, riparian and related terrestrial ecosystems are maintained or enhanced; and,

c) human life and property are not threatened by water or water-related hazards.

The concept of using watersheds and subwatersheds for land use and resource management is appropriate for a number of reasons:

1. Water continuously moves through watersheds and influences numerous life cycles and physical processes throughout its cycle.

2. An action or change in one location within a watershed has potential implications for many other natural features and processes that are linked by the interactive movement of surface and groundwater.

3. Water movement does not stop at political boundaries, so that watersheds and subwatersheds may encompass all or part of several municipalities.

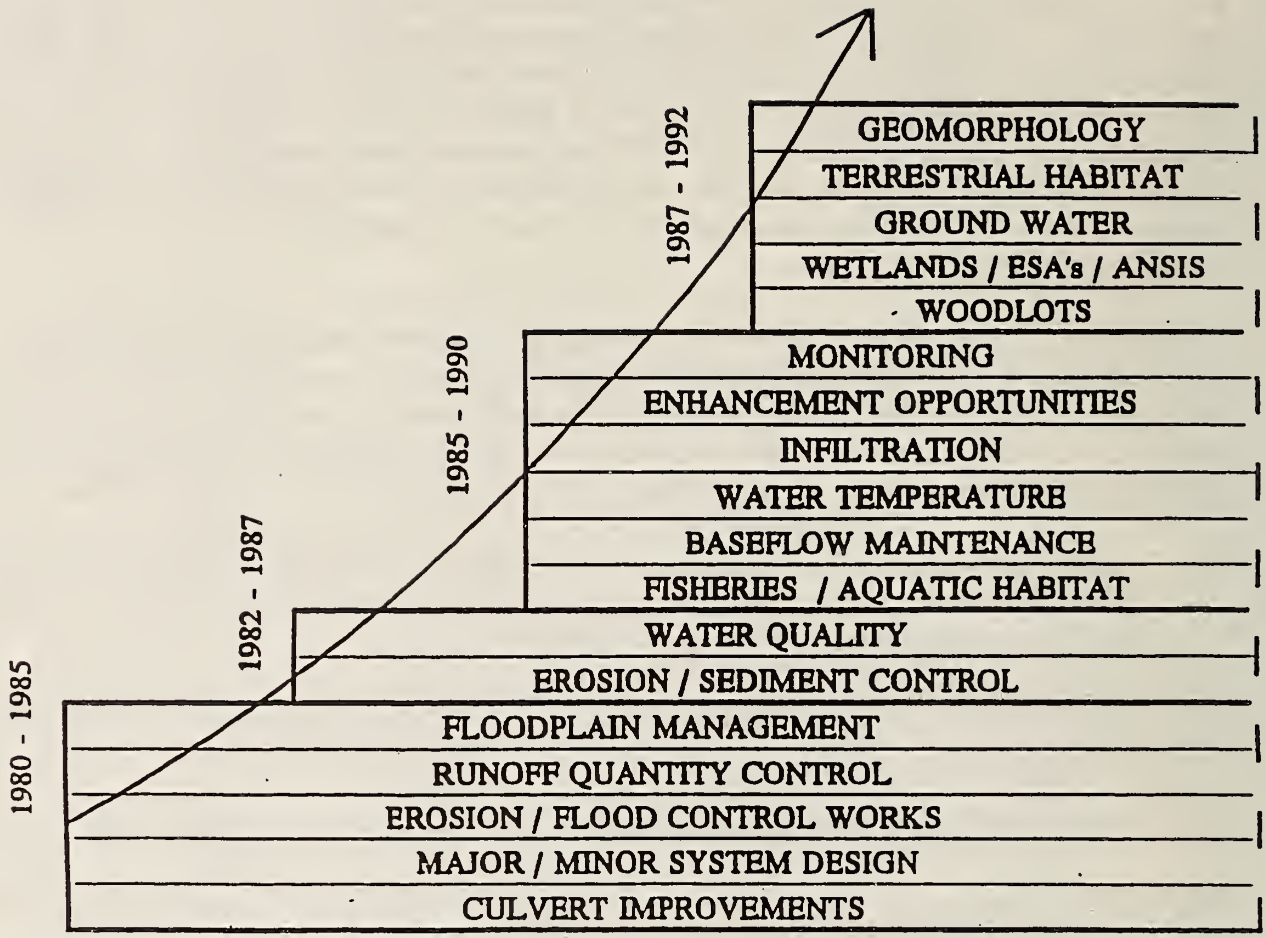

Figure 4-2 Issues Addressed in Subwatershed Plans, 1980 - 1992.

The Ganaraska Region Conservation Authority was the first agency established on a natural resource boundary basis. This occurred almost 50 years ago, in 1946. The *Conservation Authorities Act* of 1946 established "conservation authorities" with jurisdiction over natural areas based on watersheds. Conservation authorities are the only agencies in Ontario with administrative borders based on surface water drainage boundaries. This makes them particularly well suited for coordinating watershed management activities. There are 38 conservation authorities (CAs) in Ontario; five of these are in Northern Ontario.

Environmental studies have been conducted in Ontario since the 1940's, but these were largely inventories of existing conditions in the watershed. Over time, the complexity of these studies increased and evolved from simple assessments to multidisciplinary studies that are moving toward consideration of the carrying capacity and integrity of the ecosystem. Clearly, there has been a shift from remediating problems to proactively protecting and enhancing the environment.

4.3 MAJOR ENVIRONMENTAL ISSUES

Stormwater management as it is known today involves the management of a number of key issues, including considerations of flooding, baseflow, water quality, and erosion. These issues are outlined in the following sub-sections.

4.3.1 Flooding

Urbanization typically increases the fraction of the surface are which is effectively impervious. As a result, runoff peak flows are greater than would be observed in the absence of urbanization. The extent of flooding, corresponding to a relatively large rainfall event, is also increased. Therefore, policies should be included in the Official Plan which address flooding and flood-prone lands.

4.3.2 Baseflow

The passing of the *Fisheries Act* made preservation or enhancement of the physical integrity of the stream channel, water quality, and baseflow rate key issues in the development of a stormwater management plan. Baseflows are typically derived from a combination of the attenuation of surface drainage and the exfiltration of groundwater. Two extreme examples are described below to illustrate the complexity of these systems and possible SWM measures.

In watersheds where impervious soils dominate, infiltration to and exfiltration from local groundwater supplies may be limited. If the stream channel bed is well above the regional groundwater flow system and the piezometric head is insufficient to create an artesian condition, then baseflows are characteristic of surface water attenuated systems. Under such conditions detention based facilities can be used to effectively maintain baseflow rates.

In watersheds where soils are predominately pervious, infiltration to and exfiltration from local shallow groundwater supplies may be significant factors in maintaining baseflow rates. Further, if the stream channel is sufficiently incised to intercept the regional groundwater flow system,

or it is artesian in the vicinity of the stream channel, then baseflows will demonstrate the behaviour of a groundwater exfiltration-based system. In such systems preservation of the regional groundwater flow system may extend beyond the watershed under consideration and may or may not be recharged within the study watershed. However, infiltration-based BMPs are essential to the preservation of local groundwater flow systems. Recharge areas and exfiltration zones should be delimited and designed into the stormwater drainage plan such that drainage from the development is conveyed to the infiltration area(s) to minimize the alteration of the infiltration component of the hydrologic budget. Figure 4-3 illustrates the movement of precipitation within pre-urban and urban conditions. The percentages identified in Figure 3-3 are approximate and will vary from site to site.

4.3.3 Water Quality

Urban stormwater runoff carries a wide range of pollutants. Variabilities in the composition of stormwater, the sources of these contaminants, and resultant loading estimations are recognized in the presentation of average pollutant concentrations in Table 4-1. Marsalek and Ng (1989) suggest that the variations in stormwater pollutant concentrations should be considered in the context of intended use of such data, e.g., comparison of relative contributions of pollutant sources and the development of cost effective remedial measures.

Municipalities should make every effort to prevent or avoid, if possible, the discharge of untreated municipal sanitary sewage and contaminated stormwater runoff and land drainage to receiving water bodies. They should also advocate and encourage stormwater best management practices, which include management techniques.

4.3.4 Erosion

Although sediment in receiving streams occurs naturally, it is considered to be a pollutant when it accelerates the filling of reservoirs, navigatible channels and harbours; consequently burying fish spawning areas and contributing to stress on fish health, attributes to the geomorphic instability of the channel system, and so on.

Sediment in stream waters is derived from two primary sources: the tableland and the floodplain. Construction activities on the tableland results in the loss of vegetation and the disruption of surface sediments. These exposed and loosened sediments are more susceptible to entrainment and transport and, if not controlled, can significantly increase the loading of sediment in the receiving stream resulting in a myriad of negative impacts.

Mitigative measures have been developed to control sediment production from the upland area prior to its release to the receiver. Mitigative techniques include appropriate construction activities and erosion control measures, enforcement procedures and penalties for violation.

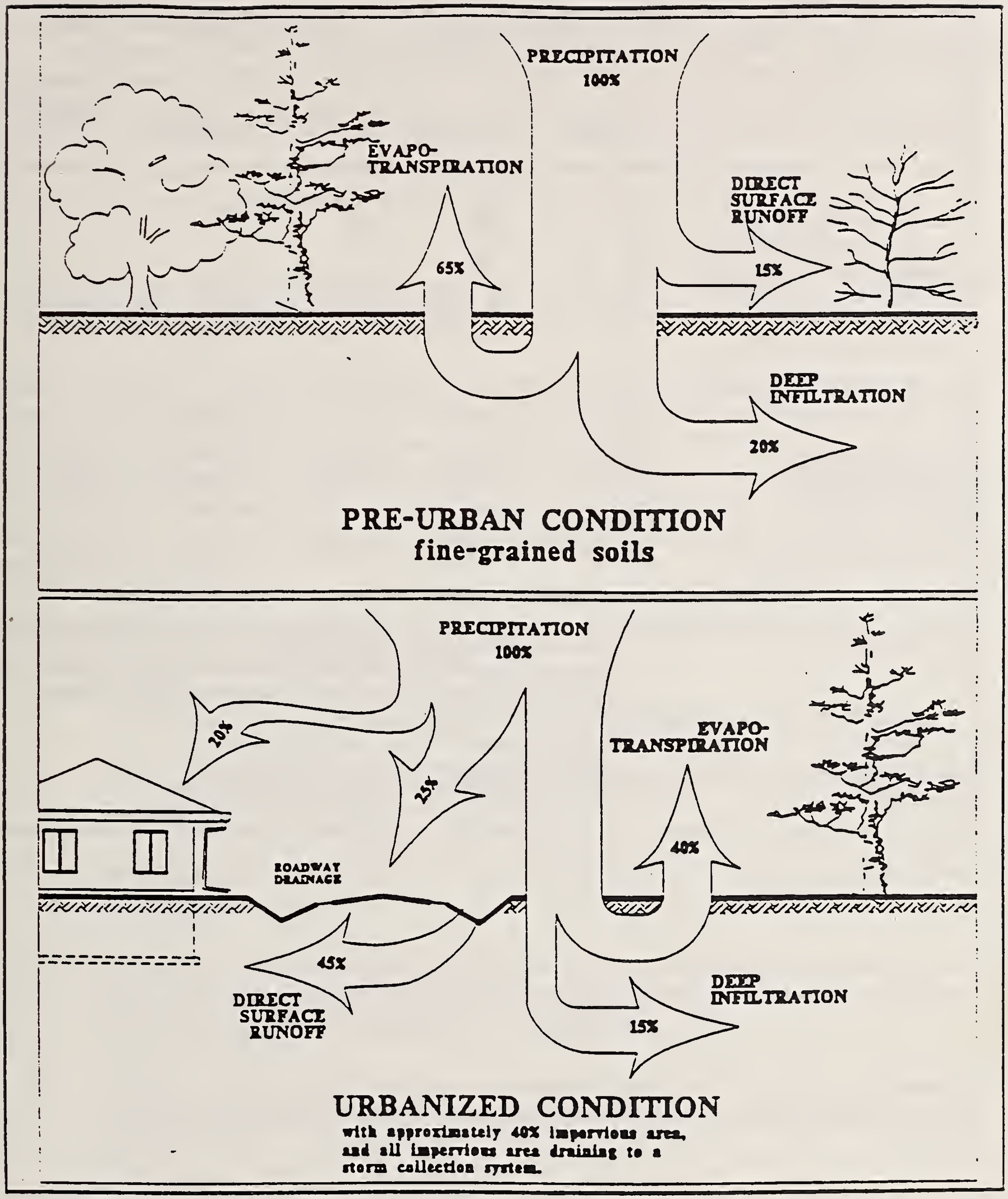

Figure 4-3 Pre-Urban and Urban Stormwater Movement.

TABLE 4-1 - URBAN STORMWATER POLLUTANT CONSITUTENT CONCENTRATIONS

Parameter	U.S. EPA[1]	East York[2]	St. Catharines[3]	Kingston[4]	Provincial Water Quality Guidelines
Total Suspended Solids (mg/L)	125	281	250	72	-
Biological Oxygen Demand (mg/L)	12	14	8.2	8.5	-
Chemical Oxygen Demand (mg/L)	80	138	-	-	-
Total Phosphorous (mg/L)	0.41	0.48	0.33	-	0.03
Soluble Phosphorous (mg/L)\	0.15	0.06	0.084	0.118	-
Total Kjeldahl Nitrogen (mg/L)	2.00	2.20	0.89	-	-
Nitrate and Nitrite (mg/L)	0.90	0.46	0.65	0.25	-
Total Copper (mg/L)	0.040	0.050	0.021	0.009	0.005
Total Lead (mg/L)	0.165	0.570	0.084	0.013	0.025
Total Zinc (mg/L)	0.210	0.330	0.100	0.064	0.030
Fecal Coliform (org/100 ml)	21,000	11,000	68,000	21,000	100

1. U.S. EPA
   - Mean concentration for median urban site Nationwide Urban Runoff Program (NURB) (Driscoll and Mangarella, 1990)
   - Fecal Coliform, Median Event Mean Concentration (EMC), 11 sites NURP (U.S. EPA, 1983)
2. East York - Arithmetic mean, 18 events, 1 site (Kromis, 1982)
3. St. Catharines - Geometric mean, 4 events, 1 site (SCAPCP, 1990)
4. Kingston - Geometric mean, 8 events, 1 site (CH2M Hill, 1990)

Following completion of the construction phase the sediment surface is stabilized through revegetation and paving, and sediment loadings decrease to near pre-development levels. However, runoff volumes and peak flow rates may increase significantly over pre-development levels. This increase in flows translates into higher instream erosion potential. This results in an accelerated release of sediment stored in the floodplain and the associated negative impacts of both channel degradation and aggradation. To offset the increase in runoff volume the Municipality should encourage the implementation of retention based source controls to the maximum degree practical. If required, downstream centralized controls, e.g. a wet pond, should then be applied to regulate the rate at which flows are released to the receiver.

4.4 RELATIONSHIP BETWEEN MUNICIPAL LAND USE PLANNING AND WATER RESOURCE PLANNING PROCESSES

Watershed planning is recognized by federal and provincial governments as being the most effective means of evaluating and developing water-related resource management strategies and practices. Most decisions that are made on privately owned lands, however, are made in the context of the municipal land use planning process on the basis of municipal boundaries or property ownership. It is very important, therefore, that there be adequate linkages established to incorporate water and related resource management directions into the municipal land use planning process.

Watershed planning and management can be considered as a five-part framework which defines, on an increasingly detailed and localized basis:

1) broad water and related resource goals and objectives on a watershed basis

2) basic management strategies identified in a watershed management plan to meet stated goals and objectives and principles

3) specific directions to guide land use planning decisions through the development of subwatershed plans

4) water resource requirements on individual land parcels through site-specific plans such as a stormwater management plan and development conditions that will meet the goals, objectives and principles of subwatershed plans

5) specific management techniques through site plan controls, stormwater management plans, subdivision agreements, and erosion and sedimentation control by-laws

These components constitute levels of planning, but also aspects of watershed management when implemented. At all levels, clear roles and responsibilities are assignable to appropriate agencies or groups, and provisions are made for full public consultation.

Under the *Planning Act*, the municipal land use planning process sets out a distinct framework for the development of environmental, social and economic goals and objectives for the municipality. Implementing the watershed planning framework often entails specific actions which fall outside of the scope of the municipal land use planning process. Furthermore, the planning process alone cannot be expected to incorporate and implement all aspects of an effective watershed planning and management process. Therefore, linkages between the two processes are very important.

4.5 POLICIES ADDRESSING WATER RESOURCE MANAGEMENT IN THE MUNICIPAL LAND USE PLANNING PROCESS

In the municipal land use planning process, the key planning document is the official plan. The official plan sets the municipality's goals and objectives for land uses within its jurisdiction. The official plan also provides specific policy direction which guides land development in accordance with provincial policies and guidelines as provided for under the *Planning Act*. *It is an important mechanism, therefore, that can be used to promote and implement the objectives of water and related resource planning. If this is done, the process can be considered to be integrated land use/ water resource municipal planning.*

In general, the policies of the official plan should clearly recognize the importance of the quality of surface water and related resources to the environmental, social and economic well being of the municipality. The policies should also reflect the municipality's commitment to maintaining the quality and quantity of water and related resources to maintain the integrity and well-being of the aquatic ecosystem. Examples of specific policies are provided below.

4.5.1 Specific Policies

Commitment to Integrated and Coordinated Water Resource Management
Municipalities should support and seek the fullest possible participation in the water and related resource management initiatives of other agencies in order to develop comprehensive integrated water and related resource planning programs.

Where a watershed plan has been prepared, for example, by a conservation authority, in consultation or partnership with the Ministries of Environment and Energy, Natural Resources and the municipality, the municipality should incorporate relevant parts of the watershed management plan into the official plan. When a watershed plan is in preparation but is not yet finalized, the municipality should state its intention to re-evaluate and, if necessary, amend its official plan to incorporate new water resource management policies contained in the watershed plan.

Maintenance of Natural Watercourses
The official plan should contain provisions to protect and maintain all lakes and streams as natural distinct ecosystems. In this regard, land within the area of influence should, wherever possible, be retained in or rehabilitated to a natural vegetated riparian state. Modification to stream or lake beds should be prohibited or limited by strict conditions.

Specific building setbacks for riparian lands should be developed in consultation with the Ministry of Natural Resources and the local conservation authority. Streams, lakes and associated setback areas, as components necessary to the integrity of natural systems, should be placed in appropriate restrictive designations and zones in the official plan and comprehensive zoning by-law. These provisions will have the effect of prohibiting the placement or removal of fill, buildings and structures, except those structures required for erosion and sedimentation control, and conservation purposes.

Control of Discharges to Surface Water and Groundwater
Municipalities should make every effort to prevent or avoid, if possible, the discharge of untreated municipal sanitary sewage and contaminated stormwater runoff and land drainage to receiving water bodies. The official plan should recognize that it is unacceptable for the municipality to route urban stormwater/drainage through concrete channels. In other words, municipal land drainage systems should be maintained in their natural conditions, and underground sewerage should be minimized. If these are required in isolated cases for the protection of life or property, however, they must comply with provincial requirements. Accordingly, municipalities should adopt by-laws to control waste discharges to municipal sewers, such as the Model Sewer Use By-law. They should also advocate and encourage stormwater best management practices, which include management techniques.

Enhancement of Water Conservation Practices
Municipalities should adopt policies to maintain and enhance water and related resources by promoting water conservation measures, developing water budgets for ground water aquifers, and should encourage innovative municipal standards such as the use of cisterns and water efficient plumbing fixtures.

Water Quality/Quantity Targets
Policies should be included in the official plan by which the municipality requires that all proposed changes in land use address potential impacts on the quality and quantity of water and related resources by:

- maintaining or enhancing the natural hydrological characteristics including the baseflow of watercourses
- maintaining storage levels in lakes during periods of minimum baseflow, where appropriate, for low flow augmentation
- requiring the development and monitoring of water budgets for ground water aquifers
- protecting or enhancing fish and wildlife habitat
- maintaining or enhancing water quality as measured by indicators such as temperature, turbidity, bacterial counts, oxygen levels and nutrients
- prohibiting, and if not possible, minimizing alterations to natural drainage systems by

maximizing the retention of natural vegetation and maintaining vegetative buffer strips along watercourses

- prohibiting, and if not possible, minimizing sediments entering a stream or lake to the greatest degree practicable

- ensuring that no persons or property are placed at increased risk due to increased flooding or erosion

These targets should be met on a watershed, subwatershed and site-specific basis.

Identification and Protection of Significant Hydrogeological Areas
Where hydrogeologic areas exist, such as recharge/discharge areas and headwaters, that are known to be susceptible to contamination, the official plan should include policies to afford them protection from potential sources of contamination. Municipalities, in consultation with the Ministry of Environment and Energy and Health Units, should control land use activities and servicing arrangements so as to reflect the location and extent of areas with differing capacities to sustain long-term operations of on-site sewage systems without ground water or surface water impairment, or risk to public health.

Protection of Inland Lakes
The official plan should include policies for developing shoreland management plans, which include setting development capacities for inland lakes. These should be developed in consultation with municipalities and agencies adjacent to the same lake system and the affected public. The intent of these policies is to prevent excessive nutrient enrichment and dissolved oxygen depletion in these lakes as a result of the cumulative impacts of shoreland development.

After establishing a sustainable level of development, the municipality will state in its official plan policies the maximum permissable number of lots allowed on each lake within a watershed and the distribution of lots among municipalities sharing the lake system shoreland.

Protection of Human Life and Property from Water-related Hazards
Policies should be included in the Official Plan to prohibit land uses which threaten human life and property due to the presence of water related hazards including:

- flood-prone lands
- soils prone to water related slope instability
- unstable soils

4.6 IMPLEMENTATION

The official plan should identify implementation schedules and mechanisms, that is, how and when the policies in the official plan will be implemented. This includes, for example, identifying when specific water and related resource planning and management tools, like subwatershed plans and stormwater management plans, will be needed. This is to ensure that

linkages between watershed and land use planning are established at the outset. These policies should be implemented through zoning by-laws.

A three-part implementation strategy is recommended:

1. Watershed Plans

Where a watershed plan has been prepared, all land use planning decisions should be carried out in accordance with the recommendations of the watershed management plan. An official plan can reflect the broad directions, goals and targets established in the watershed management plan.

2. Subwatershed Plans

For large scale and/or multi-ownership proposals normally requiring a major official plan amendment, a subwatershed plan would be very beneficial to all concerned. This should be developed and approved by the municipality and/or the conservation authority, or the Ministry of Natural Resources and Ministry of Environment and Energy where conservation authorities do not exist. The plan demonstrates how water and related resources will be managed to meet surface and ground water quality and quantity targets. The plan must examine the entire subwatershed's goals, objectives, principles and policies, and not just portions to be occupied by a development proposal. This will require cooperation with other municipal jurisdictions outside the individual area municipal boundary.

An alternative approach may be to define distinct subwatershed units on a separate schedule to the official plan, and specify the timing of studies in support of the development of a subwatershed plan. If possible, subwatershed plans and the official plan should be tied administratively in their development. The official plan should recognize the aims and contributions of watershed and subwatershed planning. This parallelism will help streamline the development approval process. *Where a watershed plan exists, the subwatershed plan will conform to the goals and objectives of the watershed plan.*

3. Site Management Plans

A variety of site-specific plans are prepared in support of draft approval of plans of subdivision, and other development applications which require the use of site plan control. Familiar examples are stormwater management plans, flood control plans, sediment and erosion control plans, and plans for servicing of roads, water and sewers. These plans specify how requisite servicing and environmental design/management needs will be addressed in a manner satisfactory to the local municipality, conservation authority, and where appropriate, provincial agencies.

When site management plans are formulated in accordance with principles and targets of the subwatershed plan, the site plans are more effective, the objectives of the subwatershed plan have practical application, and the environment generally benefits. Where this has occurred, the review agencies may consider it unnecessary to review individual site plans, because those plans have been developed according to criteria identified in the subwatershed plan. Approvals for the construction and operation of facilities identified in these plans, however, may still be

necessary under specific legislation administered by provincial ministries.

When specifications for facility design, performance and location are established in a subwatershed plan, it has been shown that both timeframes and expenditures are reduced for completing detailed field studies, design work and environmental assessments for site management facilities. The advantage of this overview of site management in the subwatershed plan is not only a set of criteria for site planners to follow, but also consideration of site management on a systemic basis. Facilities are not considered on their own but as part of a range of optional facilities and locations, for example, for stormwater management, or for flood and erosion control measures that take into account downstream considerations.

Where no subwatershed plan or watershed plan exists, it is difficult to assess overall cumulative impacts of land use on water and related resources. In these situations, measures should be taken to minimize, to the extent possible or practical, the impacts on water and related resources, in a manner satisfactory to MNR and the local conservation authority. For small-scale development proposals normally processed as severances, site planning and spot zoning by-law amendments, water resources management will be limited to the identification of specific stormwater, erosion and sedimentation control design and construction measures.

In all situations, local by-laws can be used to address routine site management requirements, e.g. topsoil protection, urban forests, sensitive terrestrial habitats.

4.7 SUMMARY

A summary of the major topics covered by this Chapter is provided below:

1. Watershed Planning Management from an Historical Perspective

   The focus of stormwater issues during the 1950s and 1960s was quantity control. Although quantity control represents an important element of stormwater management, other aspects such as quality control, erosion control and baseflow maintenance are now recognized as critical issues. Furthermore, Subwatershed Plans (plans which enable implementation of stormwater management goals) now go beyond mitigating impacts associated with development and make recommendations for the protection and enhancement of natural resources and features.

2. Major Technical Issues

   Major technical issues addressed for stormwater management are similar to those issues identified in point #1 above, and include:

- flooding protection

- baseflow maintenance

- water quality protection

- erosion

3. <u>Municipal Landuse Planning Versus Water Resources Planning</u>

Since actual land development is regulated in the context of the municipal landuse planning process, goals and objectives of water resources planning must be recognized at this level.

4. <u>Policies Addressing Water Resources Management in the Municipal Landuse Planning Process</u>

The mechanism by which municipal landuse planning and water resources issues are integrated at the municipal planning level is the Official Plan. Specific policies of importance for the Official Plan include the following:

- commitment to integrated and co-ordinated water resources management,
- maintenance of natural resources,
- control of discharges to surface water and groundwater,
- enhancement of water conservation practices,
- specific water quality and quantity targets,
- identification and protection of significant hydrogeological areas,
- protection of inland lakes, and
- protection of human life and property from water related hazards.

5. <u>Implementation</u>

The Official plan provides a framework by which stormwater management goals may be achieved. The implementation strategy includes the following components:

- Watershed Plans

- Subwatershed Plans
- Site Management Plans

Ensuring aquatic resources are protected and considered in planning decisions is accomplished by explicitly building watershed/subwatershed goals into official plans.

REFERENCES

Ministries of Environment and Energy, and Natural Resources, "Integrating Water Management Objectives into Municipal Planning Documents", June 1993, pp 12.

Royal Commission on the Future of the Toronto Waterfront (Canada), "Watershed", Interim Report, Auguest 1990, pp. 207.

STORMWATER MANAGEMENT

Emerging Planning Approaches and Control Technologies

CHAPTER 5

HYDROLOGIC SYSTEMS

CHAPTER 5

5.1 INTRODUCTION

5.1.1 Training Objectives

The objectives of this module are:

- to provide an overview of the physical conditions which are addressed in the analysis of hydrologic systems,

- to describe the basic elements of the analysis of rainfall runoff processes

The application of hydrology to problems of engineering interest is the focus of Chapter 1 and is not addressed in detail in this module.

5.1.2 Background

Hydrology is a discipline which deals with the movement of water through our environment. Although the basic principles which govern this are readily understood, the details of the processes involved can be very complex. This arises from the tremendous amount of detail which is required if hydrologic processes are to be fully described. It is obvious that water falls from the sky, and then along or through the ground, and it is generally obvious what the major routes for flow must be. However, translating this into a detailed assessment of the hydrologic process requires that one deals with such things as:

- the random variability of rainfall,
- the routing of flows through a complex network of overland channels and surfaces,
- the physics which govern infiltration and movement of water in a soil,
- the biological response to rainfall, including evapotranspiration,

and so on. This amounts to a problem which is not simple at all.

Since this is so, the science of hydrology has evolved into a practice that relies heavily on empirical relationships or concepts, that describe the major hydrologic process in a relatively gross way. Statistical and probabilistic methods are often employed to deal with uncertainty. Aside from this, there are a number of very complex and comprehensive models (that still only represent a small fraction of reality) which have been developed to describe parts of the hydrologic process that have become of interest in more detail. This leaves the hydrologist with what amounts to an art as much as a science. The present best state of the art in this field still relies heavily on the use of judgement of the practitioner to balance the complex reality with the need for useful simplifications.

5.2 BASIC HYDROLOGY

5.2.1 The Hydrologic Cycle

The hydrologic cycle is fundamental to the study of hydrology. The cycle involves movement of water through the environment. A simple illustration of the hydrologic cycle is presented graphically in Figure 5-1.

1. Water evaporates from water bodies, or is emitted through transpiration from plants, or is otherwise sent to the atmosphere.

2. The resulting water vapor is transported by air movement.

3. The vapour condenses and forms clouds, and eventually falls as precipitation.

4. Water collects and travels through the land:

    - on the land surface, it can travel overland to defined drainage routes and hence to surface water bodies, or to groundwater recharge elsewhere,

    - if it infiltrates into the ground, it may be emitted through evapotranspiration or may emerge from the groundwater system into lakes or rivers.

Of course, other factors can affect this gross picture. In particular, human activity can radically affect the movement of water through the environment. In fact, most practical applications of hydrology are intended to either i) modify the natural movement of water (as in flood control), or ii) mitigate changes to the hydrologic system that human activity has caused (as in stormwater management).

5.2.2 The Rainfall-Runoff Process

Generally, hydrology in Civil Engineering practice focuses on the part of the cycle that deals with the transformation of rain into runoff as it hits the ground. The movement of that water through channels and reservoirs is assessed as an important part of that analysis. An interest in the recharge and movement of water in the ground has more recently emerged as an important consideration. The areas of hydrology that respond to the surface components of flow can be generally grouped into rainfall-runoff processes and hydrologic routing analysis. Hydrologic routing is essentially the counterpart of the more general field of hydraulics, but developed into various accepted norms and practices that support the practice of hydrology.

To understand the models and tools which are used in the practice of hydrology, it is useful to consider the following three areas:

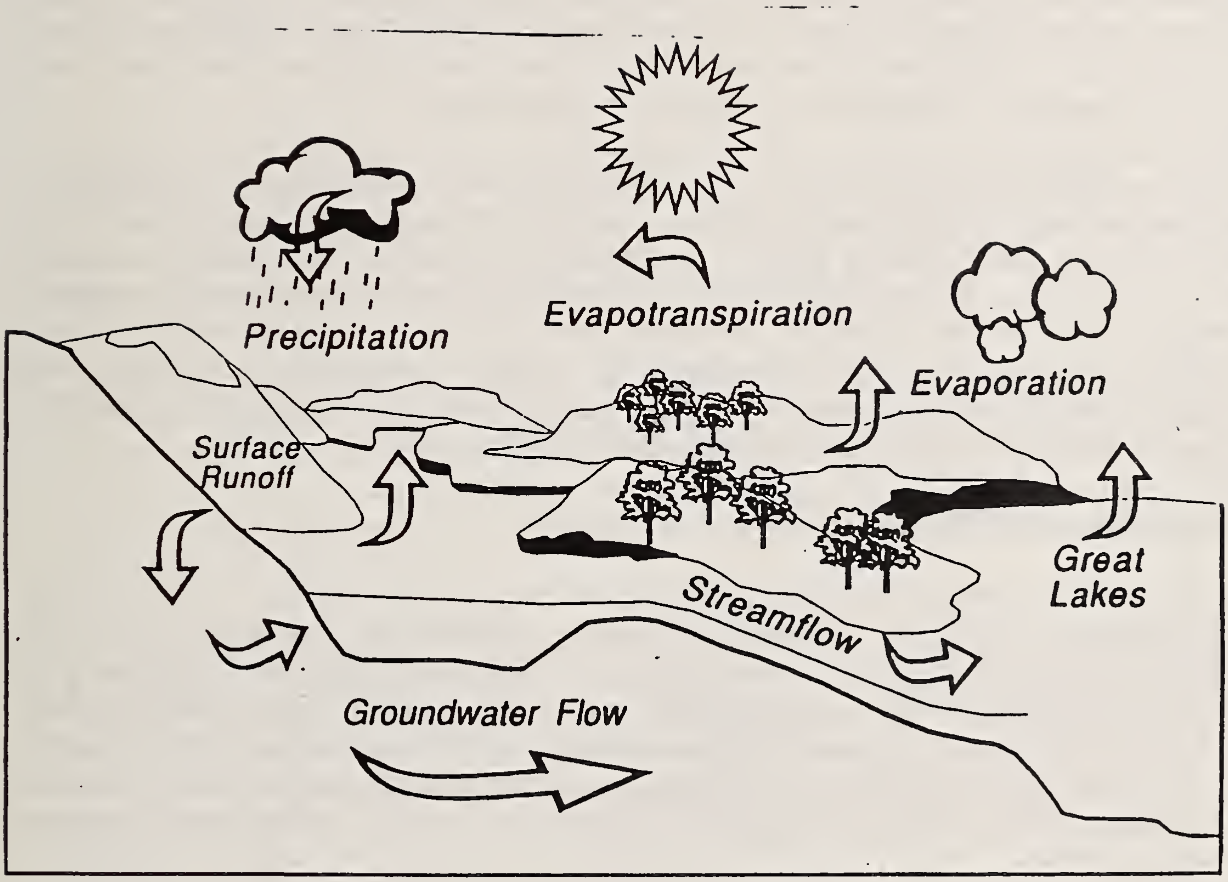

Figure 5-1 *Hydrologic Cycle*

- Loss models, that deal with the amount of water that infiltrates into the ground as rainfall hits the land surface.

- Surface routing models, that deal with conversion of volumes of excess rain into a flow rate. Excess rain is that component of rain that is not lost to infiltration, evaporation, storage, or other factors, but is available to travel across and off the catchment surface.

- Hydrologic routing models, that deal with the movement of runoff in channels and other water bodies.

Some methods of analysis group part or all of these, while others deal with them separately.

When rain falls from the sky, it is usually conceived of as an 'event' which has a characteristic volume and duration, and a pattern of intensity. Some of that rainfall infiltrates into the ground, is retained in surface depression storage, or is otherwise lost; the remainder is 'excess rainfall'. That excess rainfall volume gives rise to a period of runoff. Plotted on a graph of flow rate vs time, the pattern of runoff from the catchment usually has a shape which starts low, peaks, and tails off; this pattern of runoff rate is known as a 'hydrograph'.

One of the reasons that the science of hydrology has achieved significant importance in engineering practice, is that urbanization has a major impact on the hydrologic cycle. This impact, and the means of dealing with it, are discussed in some detail in Chapter 1. In this Chapter, it is noted that the need to understand and predict the effects of development on rainfall and runoff, as well as other aspects of the interaction of humans and their environment, have had a significant impact on the tools developed for assessing problems in hydrology. This Chapter stresses tools and concepts most commonly used in the practice of hydrology in Ontario. An extensive literature deals with many other aspects of the problem.

5.3 RAINFALL-RUNOFF ANALYSIS

Most of the models used in engineering practice are deterministic in nature. That is, they attempt to represent rainfall runoff processes by making predictions based on physical principles and without direct treatment of the element of chance. Such models might be formulated with a great deal of detail, but might represent the system in a very simplified way; either way, they address cause and effect. There has been some attention to probabilistic or stochastic methods (which represent rainfall-runoff as a random process and approach the problem quite differently than the deterministic models do). However in general these have not received major attention in applied hydrology.

Probability in most cases is applied to the estimate of rainfall or runoff event frequency, and to some degree in the estimation of variability or error in model prediction. There are some advantages to probabilistic methods, in the speed and economy with which they can identify solutions and provide estimates of hydrologic performance. However, they as yet are not the major tool of choice in stormwater management for most practitioners in Ontario.

5.3.1 Basic Concepts in Analysis

Modelling Approach

Typically, flow rate is taken to be a continuous variable, which changes in some way from one instant to another. Rainfall, on the other hand, is typically taken to have a particular intensity over one time interval and a new intensity over the next time interval, with no transition between, and therefore has the form of a discrete variable.

In either case, a variable such as runoff rate or volume can be assessed to establish the probability of any particular value which that variable might take. This can be complex. For example, one might be interested in estimating how often one will experience a particular flow rate during a snow melt period. This specific flow rate will depend on the temperature, precipitation and snow pack depth. We assume that we know or can estimate the flow associated with any combination of temperature, precipitation, and snow pack depth. We then need to estimate how likely a particular flow rate is.

A Statistical Estimate Statistical models might attempt to solve this problem by defining the individual probabilities of each variable, and the way in which those probabilities combine to provide a joint probability. Once this is done, one could i) identify all the combinations of precipitation, pack depth and temperature that produce a particular flow; ii) estimate the probability of each identified combination; and iii) add up the individual probabilities to arrive at a total probability for the flow rate.

A Continuous Simulation Estimate Continuous simulation models attempt to overcome this problem in a rather different way. Such models could be used to i) complete a long term simulation of snow pack, temperature, and precipitation records, to generate a long term estimate of flow; ii) examine this long term simulation; and, iii) count the number of times that a particular flow rate was simulated to have occurred, which provides an estimate of the probability of that flow rate.

A Single Event Estimate A compromise between the above methods is to produce flows for a particular design event condition. One could i) define a rainstorm event with a particular probability of occurrence, say, one in one hundred years, ii) simulate the result of that flow rate, and ii) consider that the simulated flow has a probability which matches that of the rainfall event, in this case a one in one hundred year frequency of occurrence. In fact, a flow derived this way has a somewhat tenuous relationship to a particular probability of flow, since the variations in catchment characteristics (soil moisture, etc.) are not accounted for in the estimate of probability. This may not necessarily be a serious problem in some situations. The need for a better estimate of probability is determined by the case at hand.

In the final analysis, it is the quality of the analysis that is important. All methods can be used to produce good or bad results. It is considered, however, that for a given level of accuracy, the effort involved in producing meaningful probabilities with continuous simulation is less than with the other methods, particularly if the physical system is complex.

5.3.2 Precipitation Analysis

Rainfall Hyetograph

Rain is usually measured in incremental volumes at gauging stations. These increments take the form of daily volume, or volume at some other increment of time. It is possible to plot the rainfall volume, or its equivalent the rainfall intensity, for incremental times during the event. The result is a plot known as a hyetograph. The shape of the hyetograph for a particular rainfall event constitutes the time history of that event.

A hyetograph can be used in single event and continuous simulation anlaysis of rainfall-runoff processes. A long-term continuous hyetograph consists of a series of rainfall pulses through time. To separate it into independent storm events, a definition of the minimum interevent time is required; the reason for this being so that any two pulses of rainfall can be considered to be belonging to separated events if the time period between the pulses is longer than the minimum interevent time. Storm event analysis can be used to determine the statistics and the probability distributions of rainfall volume, duration, average intensity, and interevent time from a long-term hyetograph. Analysis of a number of rainfall record across Canada indicates these characteristics can be described as exponential density functions. Such statistical information can be used in statistical analysis of reainfall-runoff process.

Rainfall Intensity-Duration-Frequency Curves

An observed hyetograph is useful as an indication of the severity or typical nature of rainfall events, and in calibration. However, a natural event often has little intuitive significance and no discernable probability, since there are no two events that are identical. It is therefore useful to seek alternatives to the direct use of observed rainfall events.

The most basic definition of a storm event lies in its duration and volume, and possibly in its peak intensity. In the long term, rainfall can be assessed according to the frequency at which a particular storm of a given duration and volume occurs. This relationship is defined by curves known as Intensity/ Duration/ Frequency (IDF) curves.

To generate an IDF curve, observed rainfall records are scanned for all instances of a particular combination of duration and volume; the number of times that combination occurs provides a measure of likelihood. Assessing the problem in terms of the number of times a combination is exceeded, provides a probability that expresses the frequency of exceedance of that combination. Compiling statistics for all combinations leads to curves that define the relationship between rainfall event intensity, duration, and frequency.

The Atmospheric Environmental Service (AES) defines an intensity-duration event for a particular duration, t_0, as the annual maximum intensity determined. The AES types IDF curves are derived by scanning the clocktime rainfall record with the event definition: $t <= t_o$, annual max $i = (v/t_0)$. The extreme annual series is determined, and a Type 1 extreme value distribution is used to calculate the frequency of intensity and duration.

$$i = \frac{a}{(t + b)^c} \tag{5.1}$$

where:

i = intensity (in/hr) or (mm/hr)

t = time in minutes

a, b, c = constants developed for each IDF curve.

Once an IDF relationship is developed for the area of interest, a certain combination of design intensity and duration can be determined for a particular frquency of occurrance. The IDF curves are used extensively in single event analysis of rainfall-runoff processes.

Design Events

Synthetic design events are used to provide uniformity of approach. They usually represent an attempt to define a single event that has characteristics which represent the average of the many different real events of a particular size that occur in an area.

The design storm is based upon the selection of a rainfall time-intensity pattern. IDF curves are generally used to determine a design storm. Generally, although a real storm is variable over space as well as time, design storms do not normally have a strong representation of this effect. In some cases, a factor has been applied to the storm event to reduce its intensity as larger areas are considered. This is on the assumption that it is unlikely that an event will cover an entire large catchment at a uniform intensity, since the event will tend to cover only a part of the large catchment. Fringe areas may receive less rain than the point where the storm is centered.

The choice of a design event is a significant one, since the time (and space) distribution of precipitation has a marked impact on runoff rates. For instance, if runoff from pervious areas is significant, it may be necessary to try late peaking storms in addition to early peaking storm of the same total depth. Many approaches to synthetic rainfall event definition have been proposed. Representative examples are described below.

a) Uniform Rainfall

The most basic design storm, and one of only limited use, is the uniform rainfall event. This corresponds to a point on an IDF curve.

The duration of the event matches a duration on the IDF curve. The volume of the event is selected by taking the intensity on the IDF curve, and multiplying that value by the selected event duration.

(b) Chicago Storm

The Chicago storm in essence corresponds to all points on a single Intensity/Duration (ID) line on an IDF curve. The method generates a design event which has the property that each duration and intensity along the ID line is contained in some interval (duration) in the design storm. For any particular duration on the ID line, a particular intensity exists. There is an interval in the design storm, containing the peak intensity point, which contains the same particular intensity.

This storm has an effective and useful property in that all naturally occurring intensities and durations in the watershed records are, because of the way that the storm is derived (from the IDF curve), contained in the storm. This provides a reasonable basis for design.

Although it may be considered to be somewhat too intense in the very short interval immediately around the peak of the storm, because of the way it is derived, the method is still commonly used for small to medium urbanizing watersheds (0.1 to 10 sq. mi) where times to peak are short.

c) SCS Type II Storm

This storm was derived for use as a table of values that provide hyetograph values that have a reasonably representative distribution (e.g., Table 5.1). The event shape exists for long duration (up to 48 hour) and short duration (1 hour) events. The event shape, originally developed for larger watershed areas (10 sq. mi.) rural watersheds, but has been used in small urban watersheds as well. The longer duration SCS Type II storms have used for sizing detention facilities and at the same time providing a reasonable estimate of peak flow to provide sewer system sizing estimates.

TABLE 5.1 SCS Type II Rainfall Distribution for 3,6,12, and 24 Hour Durations

3 HOUR			6 HOUR			12 HOUR			24 HOUR		
Time	F_{inc} (%)	F_{cum} (%)	Time	F_{inc} (%)	F_{cum} (%)	Time	F_{inc} (%)	F_{cum} (%)	Time	F_{inc} (%)	F_{cum} (%)
						4.5	1	1			
			4.5	2	2	1.0	1	2	2	2	2
						1.[illegible]	1	2			
0.5	4	4	1.0	2	4	2.0	1	4	4	2	4
						2.[illegible]	2	6			
			4.5	4	4	3.0	2	2	6	3	8
						4.5	2	89			
1.0	8	12	2.0	4	12	2.0	2	12	8	3	12
						4.5	3	25			
			1.[illegible]	2	89	3.0	3	89	10	3	19
						3.[illegible]	6	25			
1.[illegible]	58	70	1.0	51	70	3.0	45	70	12	51	70
						4.5	3	70			
			4.5	13	89	2.0	3	83	10	13	83
						4.5	3	89			
1.0	19	89	4.5	4	89	3.0	3	89	16	3	83
						4.5	2	91			
			4.5	4	83	2.0	2	89	10	3	83
						3.[illegible]	1	89			
1.[illegible]	7	96	4.5	4	91	10.0	2	89	10	3	96
						10.5	6	97			
			5.5	2	98	11.0	1	98	11	2	98
						11.5	1	99			
3.0	4	100	6.0	2	100	12.0	1	100	24	2	100

where F_{inc} is the incremental infiltration,
F_{cum} is the cumulative infiltration, and
Time refers to the time at the end of the time interval.

5.3.3 *Methods for Determining Runoff*

The following sections provide a cursory review of common hydrologic concepts applied in Ontario. Complete discussions should be sought in the appropriate source references. To provide a uniform and understandable approach to the discussion of equations, minor deviations from commonly used symbols have been introduced.

The Basis for a Runoff Model

Analysis of hydrologic problems such as rainfall-runoff process is done, in the majority of cases, using mathematical models of one sort or another. In general, there are three categories of model. *Unit graph models* represent the catchment as a unit hydrograph, which is assumed to represent the pattern of catchment outflow over time, resulting from rainfall after all the losses are considered. This unit hydrograph is manipulated to achieve estimates for any given event. *Coefficient models* represent the catchment as an empirical relationship between various physical parameters and a peak flow or volume. The Rational Method which historically dominates drainage planning practice is an example of this. *Physically based models* attempt to actually simulate the major physical processes which determine the relationship between rainfall and runoff.

Loss Models

A number of modelling techniques are based on effective rainfall, in which a loss model is assumed which divides the rainfall intensity into losses and effective rainfall. Common methods for estimating losses follow.

a) Volumetric Coefficient

An effective means of estimating the cumulative runoff during the course of an event is provided by the following equation:

$$Q_v = C_v * (P - I_a) \qquad \textbf{(5.2)}$$

where:
C_v = a volumetric runoff coefficient,
Q_v = cumulative event runoff, greater than zero,
P = cumulative event precipitation, and
I_a = an initial abstraction.

Incremental event runoff volumes are generated by differencing cumulative event volumes. The method is probably most effective where impervious areas predominate.

b) Soil Conservation Service Method

A relationship developed by the U.S. Soil Conservation Service, has been used in many applications in Ontario. In this method, runoff volumes are generated based on a relationship which incorporates a parameter representing soil moisture storage (S), and an initial abstraction.

$$Q = \frac{(P - I_a)^2}{P + S - I_a} \tag{5.3}$$

where: S = a loss parameter, and
I_a = initial abstraction = 0.2 S.

Incremental event runoff volumes are generated by differencing cumulative event volumes.

The retention or potential storage in the soil is established by selecting a curve number (CN) which is a function of soil type, ground cover, and Antecedent Moisture Condition (AMC).

Tables 5-2 and 5.3 indicate the specific soil types, hydrologic classification, and corresponding curve numbers associated with the Soil Conservation Service (SCS) Curve Number (CN). The SCS CN method only gives an indication of the rainfall abstraction (or rainfall losses). Part of the rainfall abstraction is infiltration which is dependent on the soil moisture condition. Antecedent Moisture Condition (AMC) II is an assumed 'average' soil moisture condition. Rainfall abstraction also includes initial abstractions such as depression storage, infiltration prior to the start of runoff, and interception. Therefore, such an analysis can only provide an approximate indication of the infiltration volume.

TABLE 5.2 Runoff Curve Numbers

Runoff curve number (CN) for selected agricultural suburban and urban land use (Antecedent Moisture Condition II and $I_a = 0.25$)				
LAND USE DESCRIPTION	HYDROLOGIC SOIL GROUP			
	A	B	C	D
Cultivated land[1] :				
without conservation treatment	72	81	86	91
with conservation treatment	62	71	74	81
Pasture or range land :				
poor condition	68	79	86	89
good condition	39	61	74	80
Meadow : good condition	30	58	71	78
Wood or Forest land :				
thin stand, poor cover, no mulch	45	61	77	83
good cover[2]	25	69	70	77
Open Spaces, lawns, parks, golf courses, cemeteries etc				
good condition: grass cover on 75% or more of the area	39	61	86	80
fair condition : grass cover on 50% to 75% of the area	49	69	74	84
Commercial and business areas (85% impervious)	81	92	94	95
Industrial districts (72% impervious)	81	98	81	93
Residential:[3]				
Average lot size — Average % impervious				
1/8 acres or less — 65	77	85	90	92
1/4 acre — 38	61	75	83	87
1/3 acre — 30	57	72	81	86
1/2 acre — 25	54	70	80	85
1 acre — 20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]	98	98	98	78
Streets and roads:				
paved with curbs and storm sewers[5]	98	98	98	98
gravel	76	85	89	91
dirt	72	82	87	89

[1] For a more detailed description of agricultural land use curve numbers refer to Nation Engineering Handbook, Section 4, Hydrology, Chapter 9, Aug. 1972.

[2] Good cover is protected from grazing and litter and brush cover soil.

[3] Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[4] The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

[5] In some warmer climates of the country a curve number of 95 may be used.

TABLE 5-3. Hydrologic Properties of Soil Types for a 2 Hour, 25 mm Storm.

SOIL TYPE	SCS HYDROLOGIC CLASSIFICATION	CURVE NUMBER AMC II[1]	RAINFALL ABSTRACTION (mm)
Sand	A	38	23.1
Sandy Loam	AB	43	22.9
Loam	A	65	20.8
Silt Loam	BC	71	19.9
Clay Loam	C	76	18.8
Clay	D	81	17.4

[1] AMC II conditions represent an assumed 'average' soil moisture condition.

c) Horton Infiltration Equation

The infiltration capacity of the soil over time (f) can be represented as an exponential transition from an initial high rate (f_o) to a lower rate (f_c).

$$f = f_c + (f_o - f_c)\, e^{-\frac{t}{k}} \tag{5.4}$$

Equation (5.4) is employed by integration to achieve an estimate of total loss, and excess rainfall is the difference between that loss and the applied rainfall. Typically, Horton's equation is applied in a model with a component that reduces runoff by an amount attributed to depression storage, similar to the above use of I_a.

The effective rainfall hyetograph is used as input to a catchment model to produce a runoff hydrograph. This approach assumes that infiltration must stop at the end of the storm.

5.4 HYDROLOGIC ROUTING ANALYSIS

5.4.1 Surface Routing Models

Several specific approaches to surface routing have tended to dominate the practice of hydrology in Ontario.

An historically important method of estimating runoff rate is the Rational Method, which relates the peak runoff rate to precipitation intensity directly. The method is not as much used now as in the past, but is still relevant to hydrologic practice. The method is formulated as follows:

$$Q = k\,C\,i\,A \tag{5.5}$$

where:

Q = peak runoff rate (L/s)
i = rainfall intensity (mm/hr)
A = land area (ha)
C = a runoff rate coefficient, and
k = a units conversion factor
= 10/3.6 (L/s per ha.mm/hr)

(Note that the rational method in imperial units gave rise to accepted coefficients which are different from the metric equivalents.)

The method can be related to the assumption that the maximum runoff rate associated with steady uniform rainfall occurs when all parts of the catchment contribute flow to the outlet.

It is important to recognise that the appropriate value of C depends on the magnitude of the storm and significantly higher values of C may be necessary for more extreme storm events (e.g. 25% increase in C for 100 year storm conditions).

The time of concentration (t_c) is comprised of two components:

- The time for overland flow to occur from a point on the perimeter of the catchment to a natural or artificial drainage conduit or channel (i.e., inlet time).
- The travel time in the conduit or channel to the outlet of the catchment (i.e., travel time).

The time of concentration is affected by a variety of physical factors, and is therefore not a constant. The time of concentration will vary according to:

- *Overland flow length*, with t_c generally proportional to length.
- *Average surface slope*, with t_c inversely proportional to surface slope.
- *Surface roughness*, with t_c is directly proportional to the roughness of the surface.
- *Depth of overland flow*, with t_c inversely proportional to flow depth.

Several methods are commonly used for estimating t_c:

- The SCS Kirpich formula, below, is used to provide a useful estimate of time of concentration as a function of maximum length of water travel, and the catchment slope.

$$t_c = 0.00013\ L^{0.77}\ S^{-0.385} \tag{5.6}$$

where:

L = maximum length of water travel, ft.
S = surface slope (H/L)
H = difference in elevation between the most remote point on the catchment and the outlet, ft.

- The Uplands method is used for estimating travel times for overland flow in watersheds with a variety of land covers. A total travel time is calculated by summing individual travel times for incremental flow lengths.

Unit Hydrograph Methods

A unit hydrograph is a distribution shape, used to represent the way that runoff leaves the catchment after one unit of rainfall excess volume is applied over a duration of one unit of time. The fundamental assumption of this method is that the runoff hydrograph follows a linear process. The unit hydrograph can be extended to other volumes and durations of excess rainfall:

- runoff from applied volumes different from one unit (over a unit of time) is estimated by multiplying ordinates of the unit hydrograph by the applied volume.

- runoff from applied volumes occurring over durations greater than one unit of time are calculated by convoluting the response to a one unit volume applied over successive one unit intervals.

The ordinates of the unit hydrograph are expressed in units of discharge per unit depth of effective rainfall.

Kinematic Routing Schemes

It is possible to estimate catchment runoff by a simulation approach based on a representation of uniform flow on a plane.

$$Q = \frac{1}{n} * D_f^{5/3} * S_c^{1/2} \tag{5.7}$$

where: Q = flow rate per unit catchment width,
S_c = catchment surface slope,
n = Manning's roughness coefficient, and

D_c = Depth of flow on the catchment.

The relation can be solved over a time step by calculating runoff rate using the above equation, and by simultaneously solving for the change in flow depth as a net result of supply (precipitation) and loss (infiltration and outflow). It is possible to incorporate detention losses by reducing D_c by the an amount taken to be a depression storage.

5.4.2 Channel Routing

There is commonly a need in the practice of hydrology to estimate the effect of channels on hydrograph peaks and distributions. There may even be a need to determine how masses of flow are increased or decreased during their passage through the channel. The process of translating a flow from a watershed through a channel is known as a 'routing'. The translation of a flow hydrograph through a reservoir is also a routing. There are a variety of ways of accomplishing the routing. These include a number of very sophisticated hydraulic models or methods that address the solution of the St. Venant equations, or other fundamental relations describing open channel flow. These are used in instances where flood flows or surges are of particular importance. Generally, these more comprehensive methods can be referred to as hydraulic routing methods.

As well, there are a number of approximations and recognized routing techniques which more simply address the same problem. These methods, suitable in the context of the practice of hydrology where peak flows and flow routing effects are important, can be termed 'hydrologic routing methods'. Several of these are described below.

The Effects of Routing

One can describe the channel routing system as a storage volume, S, which changes an input flow series, I, into an output series, Q. The storage volume is a function of depth in the channel, and of the channel shape. The input series is a function of time, and may be a hydrograph of any form. The output series, which is also a function of time, is evidently a result of the combined effect of the storage and of the input series.

The differences between the inflow hydrograph and the outflow hydrograph are either or both of i) a change in timing, or ii) a change in form. Unless a pump or other unusual condition is encountered, the net effect of routing is a reduction in peak, a delay in peak, and a spreading or flattening of the hydrograph.

Time Lag Routing

It is sometimes the case that the most significant effect of a channel is that the hydrograph is delayed, but not significantly attenuated. This can be the case where channels, particularly in the urban context, whose storage (i.e. channel volume) is limited. The lag can be estimated as a time interval T which is the time it takes water to travel the length of the channel. If this is the only feature of interest, the relation between Q and I is:

$$Q(t)=I(t-T) \tag{4.8}$$

Determination of the time lag involved may be by supposing a characteristic channel velocity over the length of the channel, or may be by using an estimation from a kinematic relationship such as the Manning Equation discussed above.

Even though the Time Lag method may be perfectly adequate, it is less often used in practice due to the simplicity and availability of other routing models.

The Muskingham Method

One of the most common methods of routing flows is the Muskingham Method. This method recognises the fact that channels often do have enough volume to attenuate a hydrograph. The method relates inflow to outflow by assessing the conservation of mass within the channel. Over a short time interval, one can write:

$$I_{avg}.\Delta t=Q_{avg}.\Delta t+\Delta S \tag{5.9}$$

or, taking the time at the beginning of the interval as 'n' and at the end as '$n+1$', can write:

$$\frac{I_n+I_{n+1}}{2}=\frac{Q_n+Q_{n+1}}{2}+\frac{S_n+S_{n+1}}{\Delta t} \tag{5.10}$$

This can be rearranged and solved for the unknown of interest, flow Q at any particular time, by knowing i) the previous flow Q, ii) the previous and present inflow, and iii) the previous amount of storage in the channel.

$$Q_{n+1}=I_n+I_{n+1}-Q_n-2.\frac{S_n+S_{n+1}}{\Delta t} \tag{5.11}$$

Since the storage S and flow Q are both unknown at the present time $n+1$, solution of this equation requires an additional condition be imposed, namely that the relation between outflow Q and channel storage S be known. This relation might take a form which depends on the Mannings equation, may be a weir curve, or may be some other functions which allow calculation of outflow as a function of the depth or volume of flow in the channel. It may be that the relation

$$Q=f(S) \tag{5.12}$$

is of a form such that substitution for S and direct solution is possible, or it may be that the form of this relation is such that an iteration is required to solve the system.

The classic Muskingham form of this relation puts the equation in terms of three coeficients, as follows:

$$Q_{n+1}=C_0.I_{n+1}+C_1.I_n+C_2.Q_n \tag{5.13}$$

Each coefficient is a function of two parameters, K and x, which can be solved graphically if an inflow and outflow hydrograph are known for a particular channel.

$$C_0=-\left(\frac{K.x-\frac{\Delta t}{2}}{K-K.x+\frac{\Delta t}{2}}\right) \tag{5.14}$$

$$C_1=\left(\frac{K.x+\frac{\Delta t}{2}}{K-K.x+\frac{\Delta t}{2}}\right) \tag{5.15}$$

$$C_2=\left(\frac{K-K.x-\frac{\Delta t}{2}}{K-K.x+\frac{\Delta t}{2}}\right) \tag{5.16}$$

To solve this system, it is recognised that cumulative storage is a linear function of the common term '$x.I + (1-x).Q$':

$$\int S.dt=f(x.I+(1-x).Q) \tag{5.17}$$

Trial values of x are selected, and when a straight line plot appears, the value of x has been determined, and the slope of that straight line has the value of K. In fact, hand solution of the method is rarely done at present. However, the basic assumptions of continuity and of flow as a function of storage remain the foundation of most hydrologic routing methods.

Reservoir Routing

A major facet of stormwater management is in the need to control peak flows. This commonly is done by means of a reservoir, which may retain or detain the hydrograph and thereby reduce peaks. This need makes reservoir routing an important part of hydrologic analysis. Again, there are a number of models and approaches which have been offered, but the commonality of most approaches is that:

- the reservoir is taken as a volume which has a storage that is not dependent on surface slope (the surface is flat)

- the reservoir has an outlet which uniquely determines outflow as a function of elevation of water in the reservoir (a pipe or similar device)

These assumptions are reasonable in most urban hydrology applications, and allow a convienient approach to reservoir routing, which is strongly related to the channel routing described above. As before, continuity is applied, and leads to a form which conveniently can be solved using techniques quite similar to the channel routing schemes introduced above.

Commonly, equation (5.10) is re-written in a form with all unknowns on one side, as follows:

$$\frac{2.S_{n+1}}{\Delta t}+Q_{n+1}=\frac{2.S_n}{\Delta t}-Q_n+I_n+I_{n+1} \qquad (5.18)$$

The right hand side of (5.18) is all known, from conditions at the end of the previous time step. The value of the left hand side is therefore known for the new time step. Since the relation between S and Q is known, as a function of the outlet from the reservoir, it is possible to calculate the value of term on the left hand side as a function of reservoir storage or depth D:

$$\frac{2.S_{n+1}}{\Delta t}+Q_{n+1}=f_1(S)=f_2(D) \qquad (5.19)$$

In short, by plotting the relation $f_1(S)$ against S, or $f_2(D)$ against D, one can solve for storage and hence outflow from the reservoir at any time, if conditions at the end of the previous time step are known.

Variations of solution technique exist, but the basic principle in reservoir routing remains fairly common to the above sequence in most models. More complex reservoir models tend to

concentrate more on operation or internal mixing issues as the next step in complexity, rather than on more sophisticated routing schemes.

5.5 SINGLE EVENT AND CONTINUOUS SIMULATION METHODS

The above algorithms for infiltration and routing processes can be packaged in single event models, or in continuous simulation models. The two are differentiated by:

- the computer code which allows the model to read long term precipitation records vs short term single event records, and

- the existence of algorithms which allow the model to simulate inter-event recovery.

The capacity of the soil to absorb moisture is not infinite, and neither is the capacity of depressions and other features that result in an initial abstraction. The continuous simulation model therefore has some means of having the appropriate parameters recover between events. Otherwise, the models types are not necessarily intrinsically different. The most pronounced differences in model function are related more to the needs of the user (i.e. short term, short time step information for design, compared to long term seasonally varied information for planning) than to hydrologic principles.

Mechanisms for this recovery can be physically based (using, for instance evaporation records to estimate the recovery of initial abstraction), empirical (using a recovery curve as a function of time only), or may lie somewhere in between (using a recovery algorithm which relates event recovery to a history of rainfall coupled to an empirical recovery rate). These are all potentially useful and reasonable, provided that they are correctly employed.

Continuous analysis involves the use of precipitation and other meteorological inputs to derive stormwater runoff for the entire year(s). Accordingly, most processes of the hydrologic cycle must be simulated such as snow accumulation and melt, evapotranspiration, infiltration, and runoff.

Continuous analysis is recommended for the estimation of BMP storage volumes. Continuous simulation has several advantages over precipitation design storms and design runoff events such as:

- Snow accumulation and melt is considered (spring runoff timing).
- The entire volume of runoff is routed through the design storage.
- Consideration is given to the runoff timing related to retention time.
- The relationship between precipitation and runoff is considered.
- Seasonal effects of runoff are considered (longer storms in the spring, more shorter storms in the summer).
- Continuous analysis results can be used to predict other essential watercourse characteristics (bedload movement and channel morphology responses).

For these and other reasons, continuous simulation is becoming a dominant part of hydrologic analysis.

The resulting runoff series should be analyzed on a seasonal basis to determine the appropriate BMP storage value. A seasonal analysis should be performed since there are seasonal effects for both water quality concerns and BMPs themselves.

On a watershed scale, or large master drainage area scale, continuous analysis could involve the use of relatively sophisticated models, and there is also the possibility of using simpler methods and equally effective methods for either regional or local water quality analyses. The results from a regional analysis could be easily extrapolated for use at a local level. In this sense, the local water quality BMP would still be designed based on some form of continuous analysis.

A variety of design event and continuous simulation models have been used in Ontario. Continuous simulation models which have been used include:

STORM: An early but very effective model targeted at Combined Sewage Control studies but generally useful in stormwater management. The model employs a variation of the SCS method and unit hydrograph techniques for hydrologic analysis.

SWMM: The dominant model in North American practice in urban hydrology, most commonly used in design event applications, but effective for continuous simulation as well. The model uses a kinematic routing scheme and several loss models, including Horton's equation, to represent surface hydrology.

HSPF: A major and complex model with comprehensive capabilities, requiring major data and other resources for use, but effective in undeveloped watersheds undergoing urbanization. A physically based model with a variety of soil and surface routing options available to represent hydrologic behavior.

QUALHYMO: A comprehensive model with applicability to BMP design and analysis of urbanization in developing watersheds. The model uses a variation of the SCS method and unit hydrograph techniques for hydrologic analysis.

GAWSER: A watershed model with effective algorithms for application to rural watersheds. Contains algorithms representative of physical processes, and originally developed for application in agricultural watersheds.

OTTSWMM: A variation on SWMM, with similar general capabilities, but focused on major/minor system analysis in urban watersheds.

Numerous others can be cited, and the field is still evolving. Selection of models should be done with care and in light of the particular application. The need for BMP analysis, extensive evaluation of river or lake impacts, design or planning assessments, or other factors will all have a strong impact on the 'best' model for the job. Ultimately, however, it is the ability of the modeler which is most important in deciding the outcome of a modelling exercise.